Section 2.1

Shielding and Confinement

BNFL Inc.

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Section 2.1
Shielding and Confinement

2.1.1. Vessels

2.1.1.1. Purpose

The purpose of vessels is to provide primary confinement of the process fluids, gases, solids. They are also integral to part of the process systems.

2.1.1.2. Description

Vessels provide a major contribution to ensuring that primary confinement is maintained during the life of nuclear chemical plants.

It was with this in mind that BNFL produced a vessel design manual which identifies a set of vessel groups which covers all vessels used in nuclear chemical plants.

2.1.1.2.1. Purpose of Vessel Design Groups

The establishment of the vessel design manuals and the vessel design groups constitutes an authoritative design philosophy which ensures:

- The design standards are always consistent with the safety and commercial considerations; in particular, they ensure that the level of integrity of design of vessels is related to the potential hazard involved.
- To ensure uniformity of design to enable the economic benefits of standardization are achieved.
- To enable design justification reports to be prepared so that authorizing authorities can readily understand the design intent philosophy.
- To facilitate the specifications of administrative documentation and procedures (e.g., Quality Assurance procedures) appropriate to each group of vessels.

2.1.1.2.2. Criteria for Vessel Groupings

The most important parameters affecting the design specification of the vessels are identified as:

- Consequence of Failure
  - High risk of exposure to the workers, co-located workers and the public.
- Leakage of hazardous contents (non-nuclear hazards).

- Hazard from energy available from the confinement of pneumatic pressure and/or high-temperature gases (including steam).

- Cost of replacement or repair.

- Process can continue without repair.

Five vessel groups were chosen which accommodate the variation in the above parameters for the established varieties of vessels. These vessels have designations from Group 1 (for highest integrity) to Group 5 (for commercial integrity).

2.1.1.2.3. Design Manuals

Choice of Design Codes

Both BS-5500 Fired Fusion Welded Pressure Vessels, and ASME Boiler and Pressure Vessel Code Section VIII cover the design of pressure vessels for differing classes or categories of integrity, the difference between the classes basically being the allowable fabricational details and level of stress analysis, inspection and nondestructive testing required to give assurance that the level of integrity has been achieved.

2.1.1.2.4. Design Safety Features Incorporated Into Vessels by Design Qualification

Seismic Loading

Vessels subject to seismic qualification are classified as a safety-related vessel or a good practices vessel. Safety-related vessels are those whose failure under seismic loading have safety implications, whereas, good practices vessels are those whose failure under seismic loading have no safety implications but, because of commercial reasons, it is considered that some degree of seismic design should be considered. Such vessels are not required to remain operable during or after a seismic event but must maintain confinement, and must remain attached to their supports.

Materials of Construction

Materials will be in accordance with ASTM specifications. Where the material procurement specification allows a negative thickness tolerance, it shall be reflected in the design qualification. BNFL’s material procurement policy also ensures that material is purchased from a preferred supplier’s list.

Material Thickness

The as-fabricated thickness used for stress analysis purposes referred to as the design thickness is the minimum allowed by the specifications. In particular, the design thickness will take into account the tolerance on material thickness as purchased and any thickness reduction resulting from forming operations.

The fully corroded material thickness used for stress analysis purposes, which is termed the design corroded thickness, will be the minimum allowed by the specifications less the specified corrosion allowance for each corroded surface.

<u>Material Specification</u>

It is essential that all material requirements are clearly defined in the vessel specification. Listed below are some of the material requirements:

- Special restrictions on carbon
- Carbon equivalent or any other element
- Surface finish
- Requirements for acceptable method of plate markings
- Flatness tolerance
- Thickness tolerance

<u>Design Specifications</u>

Group 1 vessels would typically be designed in accordance with ASME VIII, Div. 1 supplemented by the Group 1 requirements of the BNFL vessel design manual.

2.1.1.2.5. Qualification Procedures

<u>Qualification for Other than Seismic Loadings</u>

Group 1 vessels would be subject to the following qualification procedure for all loadings other than seismic:

(a) A judgment shall be made as to whether the vessel or parts thereof would be qualified by formula, by analysis or by comparison with other vessels. Factors to be considered when making this judgement are:

(i) complexity of vessel
(ii) geometric shape of vessel and component parts
(iii) complexity of loading
(iv) severity of thermal loading and expansion effects
(v) effects of any superimposed loadings
(vi) effects of any dynamic loadings
(vii) availability of similar designs/loadings for comparison
(viii) anticipated maximum actual/allowable stress ratio (evaluated from simplified calculations)

The decision on the qualification route would be taken by a senior vessel engineer who would ensure that the reasoning and justification for the judgment are fully recorded and approved.

(b) Where qualification by formula is judged to be appropriate, then the qualification would be in accordance with ASME VIII Div. 1. Where no suitable formula is available from that code then formulae from other authoritative sources are used. Such formulae would be of equivalent accuracy and veracity as those present in the code.

(c) Where qualification by analysis is judged to be required, this would be in accordance with ASME VIII Div. 2, Appendix 4. Other authoritative methods of analysis may be used where they are deemed by a senior engineer to be of equal accuracy and veracity. For complex loadings or geometries, it may be deemed necessary to employ finite element techniques. The results of all analyses would be assessed against the criteria and limits of ASME VIII Div 2, Appendix 4.

(d) Where qualification by comparison is judged to be suitable, the establishment of the comparability would be justified and recorded in detail in the design calculations together with the file identification of the original referenced vessel design. Qualification by comparison would only be carried out against an existing approved BNFL design.

For Group 1 vessels subjected to significant service cyclic duty, component parts would be qualified by completion of a fatigue assessment. The only conditions under which a fatigue assessment may be waived is where there is experience with comparable equipment having similar materials of construction, similar construction features, similar stress levels and operating under similar environmental conditions. In such cases, the comparability and experience of service would be fully documented and approved by a senior vessel engineer.

2.1.1.2.6. Fabrication Specifications

Austenitic Stainless Steel

Fabrication for austenitic stainless steel Group 1 vessels would be in accordance with company standards.

Other Materials

Fabrication requirements for materials other than austenitic stainless steel would be as defined by ASME VIII Div. 1. When calling up such a requirement, consideration would be given to the need for a supplementary specification. Where a supplementary specification is written it would be subject to approval by the Mechanical Functional Manager.

2.1.1.2.7. Nondestructive Examination Requirements

Radiography Requirements

Typically, the following weldments shall be subject to 100% radiography:

(a) All welds forming part of the principal confinement, including weldments joining branches to the vessel shell.

(b) All weldments forming part of the “Other than principal confinement” where the weld is critical to the support of the structural load and the primary load is taken through the weld in tension or shear. The “structural load” would include the load resulting from the support of the vessel internals.

(c) All welds forming part of the jacket confinement, including branches penetrating the jacket, where preservation of the jacket confinement is essential to the continued operation of the vessel. If the jacket is in sections (and it is not credible that a sufficient number of sections would fail so as to cause the operability of the vessel to be affected) and/or minor leaks are admissible, consideration may be given to deleting the requirement for radiography.

(d) All welds forming joins in cooling or heating coils.

(e) All welds forming joins in dip pipes where minor leaks cannot be tolerated, e.g., level indicators, SG indicators, foam indicators. (Guide tubes for thermocouples, sample bottles and ultrasonic probes do not require radiography, excepting that guide tubes for thermocouples will be radiographed when the design pressure of the vessel in which it is installed exceeds 0.5 barg.).

(f) All welds forming joins in ejector assemblies.

(g) All welds forming joins in fluidic pump assemblies.
All main seams in "other than principal confinement" when the product of volume and internal pressure exceeds 10,000 bar-gallons or the pressure exceeds 8 barg.

(i) For multi-chambered vessels, where an adjacent chamber is categorized other than Group 1, all interconnecting weldments which provide confinement between the two chambers would be radiographed to Group 1 requirements.

(j) For serpentine coaxial pipe heat exchangers, it is essential to establish a precise build sequence which provides for the necessary access to carry out radiography and any required repairs on all inner pipe welds prior to welding the outer pipe components.

Where a weld is located so that only part of its length lies in a region requiring radiography, the complete weld would be radiographed.

For shell and tube type heat exchangers where an in-bore welding technique is used for tube-to-tubeplate welds of the butt-fillet type, the minimum clearance between tubes shall be 0.4 inches. This clearance is required to permit suitable location of film appropriate to radiographic techniques normally employed on such joints.

<u>Requirements for Ultrasonic Examination</u>

Where components are attached to any part of the vessel by a full or partial penetration tee weld (including a corner weld), and the loading results in significant through-thickness stresses in the vessel, then the parent plate in the vicinity of the weld would be ultrasonically tested prior to welding to ensure that no defects are present which could result in laminar type tearing during welding.

In particular, the following components are always examined as detailed above:

(i) Lifting lugs which are attached by full or partial penetration welds.

(ii) Supports for vessel internals (e.g., coil hangers).

(iii) Vessel supports where the type of support imposes significant through-thickness stresses in the material to which the supports are attached and the support load is taken by a small local area of the vessel.

2.1.1.2.8. Design Considerations for Minimizing Corrosion and Mechanical Damage

Introduction

The following information on corrosion and mechanical damage is primarily concerned with austenitic stainless steel which is the primary constructional material for vessels and pipework in BNFL. For other materials (e.g., titanium and zirconium for high temperature, high molarity acid, nickel alloys for high temperature caustic) advice would be sought from the BNFL Materials and Fabrication Technology Group (M&FTG).

Corrosion Audits

Corrosion audits on standard BNFL forms would be requested from the M&FTG. When requesting a corrosion audit, the following information would be provided:

(a) A completed Process Data sheet.

(b) A completed Vessel Data Sheet (including General Arrangement Drawing and special details).

(c) A brief description of the function of the vessel (e.g., the first section of the Vessel Design Report).

Pitting Corrosion

Pitting corrosion can take place in austenitic stainless steels and usually occurs due to the presence of reducing species such as chlorides, fluorides and sulphates. However, the efficacy of these species depends very much on the presence of other species particularly nitrates. If such reducing species are present, then advice would be sought from M&FTG.

Crevice Corrosion

- General

Crevice corrosion is a form of localized corrosion that can occur within crevices, or at shielded surfaces where a stagnant solution is present, e.g., at metal/metal or metal/non-metal junctions such as bolts, gaskets and valve seats. The presence of solid precipitates/sludges can also create crevice corrosion conditions. Crevice corrosion occurs in gaps up to a few microns wide and is generally not found in wide grooves or slots where circulation of the corrodent is possible. However, there are no hard and fast rules as to the dimensions of a crevice which will act as a corrosion site.

In the case of austenitic stainless steels, crevice corrosion is usually associated with aqueous chloride-containing solutions or in high temperature nitric acid environments.

- Aqueous Chloride - Containing Solutions

It is not possible to define precise environmental limits for crevice corrosion as most stainless steel/chloride solution combinations will give rise to the phenomenon under suitable conditions of geometry. The level of chloride present is important as would be expected: for example, at 30^{o}C , 300ppm chloride causes crevice corrosion but 10 ppm does not. However, the presence of radiation markedly lowers the levels of tolerable chlorides and the presence of other species, particularly nitrates, markedly raises these levels.

- High-Temperature Nitric Acid Environments

Crevice corrosion can also occur in high temperature nitric acid environments, especially at surfaces at which boiling is occurring; in general, crevices should be avoided in highly oxidizing conditions -- say greater than 6M HNO_3 (~32%) and temperatures greater than 100°C.

Wherever appropriate, the vessel designer would observe the following recommendations:

(a) Shielded areas where concentration can occur or moisture deposits can collect should be avoided.

(b) Flanged joints, bolted seams and expanded - in tubes should be avoided.

(c) Rounded contours and corners should be used where possible.

(d) Partial penetration welds should be avoided.

(e) Concentration effects by evaporation or wetting and drying should be avoided.

(f) Where crevices are unavoidable consider the use of better materials. For example, in the presence of aqueous liquors containing high levels of chlorides, 316L is superior to 304L in the austenitic series of stainless steels and duplex stainless steels are superior to austenitics.

<u>Galvanic Corrosion</u>

When a metal is immersed in a liquid, it will establish a corrosion potential or rest potential, E_{corr}, at which the rate of anodic reaction is equal to the rate of cathodic reaction. When two dissimilar metals are placed in electrical contact in such a solution, an electrochemical cell will be set up and the difference in their rest potentials will cause a current to flow between them. The less noble metal will become the anode of this cell and will suffer increased corrosion while the more noble metal will become the cathode and corrode less than when uncoupled. The additional corrosion that takes place on the anode as a result of this current flow is known as galvanic corrosion (also referred to as bi-metallic or dissimilar metal corrosion).

A galvanic series may be a useful aid in predicting whether or not galvanic corrosion will take place between two metals in a specific electrolyte. A galvanic series is a list of metals arranged in order of increasing E_{corr} in the electrolyte that is being considered. The relative position of two metals in the series will predict which will be the anode of the cell, and thus liable to corrosion, while the greater the difference in potential between the metals, the more severe the galvanic corrosion will be.
Although galvanic series of metals exist for some aqueous environments, a galvanic series of metals in nitric acid is not currently available.

Where feasible, the vessel designer would observe the following recommendations:

(a) Metals which are remote from each other in the galvanic series should not be used together. Conversely, those close together usually do not give problems. Different grades of austenitic stainless steel are acceptable in contact with each other in most environments.

(b) Where this is not possible:

(i) Always maximize the area of anodic metals and minimize the area of cathode in order to minimize the corrosion current density and therefore the corrosion rate of the anode.

(ii) The dissimilar metals should be electrically isolated from each other with the use of insulating washers, gaskets, or bushes. Alternatively both metals may be painted or coated in some way to insulate them from the solution. If it is only possible to coat one of the metals then the cathode should be coated. If the cathodic reaction can be prevented then the corrosion of the anode will be less severe. If the anode is coated, any flaw in the coating will result in severe localized corrosion of the anode.

Stress Corrosion Cracking

Stress Corrosion Cracking (SCC) is a mechanical - environmental failure process in which the combination of a tensile stress and corrosion attack results in initiation and propagation of metal fracture. The cracks form roughly at right-angles to the direction of the tensile stress. Failure in austenitic stainless steels is usually associated with chloride-containing solutions.

SCC of austenitic stainless steels is not a problem at ambient temperatures and is rare at temperatures below 60°C. Chloride cracking is still unusual in the temperature range 60-100°C but can occur provided the material is exposed for very long times. It has been suggested that maximum susceptibility to racking is in the temperature range 150-250°C and for such conditions BNFL have utilized nickel based alloys.

The possibility of SCC occurring will be minimized by:

(a) Minimizing stress levels
(b) Avoiding surface notches and rough machining marks.
(c) Avoiding pockets where fluids can accumulate.
(d) Avoiding contact with sources of chloride, e.g., insulation.
(e) Avoiding concentration of fluids on the metal surface by evaporation.
(f) Avoiding areas where splashing can occur.
(g) Choosing SCC resistant materials.

End-Grain Corrosion

End-grain corrosion is preferential corrosion which occurs along the worked direction of wrought stainless steels exposed to highly oxidizing acid conditions. This attack occurs along the rolling direction for plate, the drawing axis for tube or bar and the flow lines in forgings. The exact mechanism of end grain corrosion is not understood and its occurrence is somewhat unpredictable.

Although weld overlaying (buttering), when correctly applied, has been shown to offer short-term protection from end grain corrosion, long term protection is not guaranteed and it may be necessary to resort to stainless steels which have been given additional refining treatments such as Electro-Slag Refining (ESR) to improve their metallurgical cleanliness.

Weldments

- Sensitization

The fabrication of plant by welding involves the metal components being taken through a series of complex temperature cycles. This cycling can affect the subsequent corrosion resistance of the metal.

Stainless steels rely on the formation of a chromium rich oxide film at their surfaces to give them their characteristic corrosion resistance. During welding the increase in temperature allows carbon and metal atoms to diffuse and react within the metal matrix. At temperatures of about 700°C the metal atoms remain relatively static whilst the carbon atoms diffuse more rapidly by an interstitial diffusion mechanism. At these temperatures, chromium-rich carbides precipitate leaving chromium-depleted regions round the carbides. The carbides preferentially precipitate at grain boundaries and in severe cases a continuous network of chromium-depleted metal forms. The stainless steel is then said to be sensitized and during exposure to plant liquors relatively rapid corrosion may occur in the chromium-depleted regions.

Several factors affect the development of sensitization during the welding of stainless steels:

- Carbon in Solid Solution

Reducing the carbon content of stainless steels lowers the extent of carbide precipitation thus reducing the development of sensitization; hence, the widespread use of the "L" grades such as 304L and 316L. In some stainless steels, stabilizing elements such as titanium or niobium are added to react with the carbon, thus reducing the carbon in solid solution--such grades are 321 and 347.

- Time at Sensitizing Temperature

The longer that stainless steel is held in the sensitizing temperature range the greater the amount of diffusion which can occur. For this reason the amount of heat applied during welding should be minimized and the rate of cooling after welding should be as rapid as possible. Multipass welds on thick metal are the most likely problem areas and repair welding obviously involves increasing the total time at elevated temperatures. For these reasons, not more than three attempts to remove weld defects in the same area are usually permitted.

- Stresses Associated with Welding

The stress developed within stainless steels during welding can influence the rate of carbide nucleation and therefore the rate at which sensitization develops.

- Knife-Line Corrosion

Welding titanium-stabilized alloys can lead to the development of a very localized area which is sensitive to corrosion in oxidizing environments. During welding, titanium carbides are taken into solution in regions of the metal which are heated to temperatures in excess of about 1000°C. This occurs in a narrow band immediately adjacent to the weld. During cooling or subsequent heating to lower temperatures the titanium may precipitate as carbide in a continuous film. During later exposure to oxidizing environments, such as hot nitric acid, the titanium carbide is corroded leading to rapid attack at a line adjacent to the weld. For this reason, titanium stabilized alloys should not be used for the construction of chemical plant which will be exposed to oxidizing environments.

- Mechanical Defects

Porosity or cracks associated with welding can act as crevices and lead to the development of localized crevice type corrosion during later exposure. All welds should be checked for defects and ground back to give a smooth surface finish.

Fretting and Wear

Fretting and wear result from the rubbing of two contacting surfaces. Fretting occurs at low amplitudes and results in pit-type defects. Wear is a gouging action resulting in bulk removal of metal.

There is no load or amplitude at which wear does not occur.

Hard materials are generally more wear resistant than softer materials.

Hard particles such as spalled oxide or cracked ceramics trapped between the two surfaces are detrimental as they will abrade any surface softer than they are. With dissimilar metal surfaces, the abrasive may embed in the softer material causing severe wear of the harder.

Wear of austenitic stainless steel is more severe in nitric acid than in water or air.

Generally, increasing the temperature increases the wear.

Erosion

- General

This is the removal of material from a metal surface by the action of solid particles in a moving fluid. When erosion is encountered, guidance is obtained from the M&FTG.

Galling and Seizure

Where two metals are moving in contact with each other without lubrication, there is a risk of damage to their surfaces. In the case of stainless steels in radiation environments, lubrication is usually avoided (the lubricant breaks down due to radiolysis or is avoided because of the potential to pick up contamination) and this can lead to galling - deep scoring, gouging and cold welding of surfaces. This can occur in a very low number of cycles - for example, a bolt can gall in a few turns and seize up completely.

The best solution is to use material grades which are less susceptible to galling.

Protection for Transport and Storage

It is recommended practice for all metal stock and fabricated components to receive temporary protection to prevent corrosion or surface contamination occurring during the interval between manufacture and introduction into service. The choice of a suitable protection will depend upon various factors, in particular:

a. The material
b. The component geometry
c. The exposure time
d. Temperature
e. Humidity

Atmospheric corrosion occurs due to reaction of the metal with oxygen, moisture and any chemical pollutants present such as sulphurous compounds in industrial environments or chloride-containing salt spray in coastal areas.

Ideally, items would be unwrapped and stored on racks in heated buildings. If this is not feasible the vessel designer should observe the following recommendations for stainless steel vessels:

(a) All surface contamination, mill scale, adhesive tape, paint, dust, pickling solution, and flux residue removed. If chlorinated hydrocarbons are used for cleaning then the surfaces should be washed with water. The vessel surfaces should be left in a clean and dry condition.

(b) All openings in the vessel should be securely capped.

(c) Desiccants should be introduced into the vessel in amounts calculated for the particular volume of vessel. Vessels should be given a prior purge with dry air.

(d) Items should then be sealed inside polyethylene bags.

(e) Small items should be crated to avoid damage to the polyethylene confinement.

(f) Items should be stored under cover until required.

Transportation requirements should be as specified by the appropriate Standard Vessel Transportation Requirements sheets.

2.1.22.13 Recommended Contact Materials

Stainless steels can corrode as a consequence of being in contact with other materials. This corrosion may be as a result of the contact material itself being corrosive or because the contact material enables a corrosion phenomenon such as crevice corrosion to occur in an otherwise innocuous environment.

The preceding information taken from Corporate documents is not complete but gives indication of some of the design safety features BNFL incorporated into their vessel design.

2.1.1.3. Hazardous Situations

Hazards are typically loss of primary confinement, either in cell or out cell. Loss of confinement in-cell, does not immediately pose a hazard, but does place demands on other safety systems.

Two primary mechanisms for loss of confinement are loss of vessel integrity (e.g., leaks) or overflow (see Figure 2.1–1).

The set of Important to Safety SSCs for these hazardous situations is provided in the following tables. The tables also identify Safety Functions and Design Safety Features.

Figure 2.1-1. Typical Vessel Overflow Arrangement

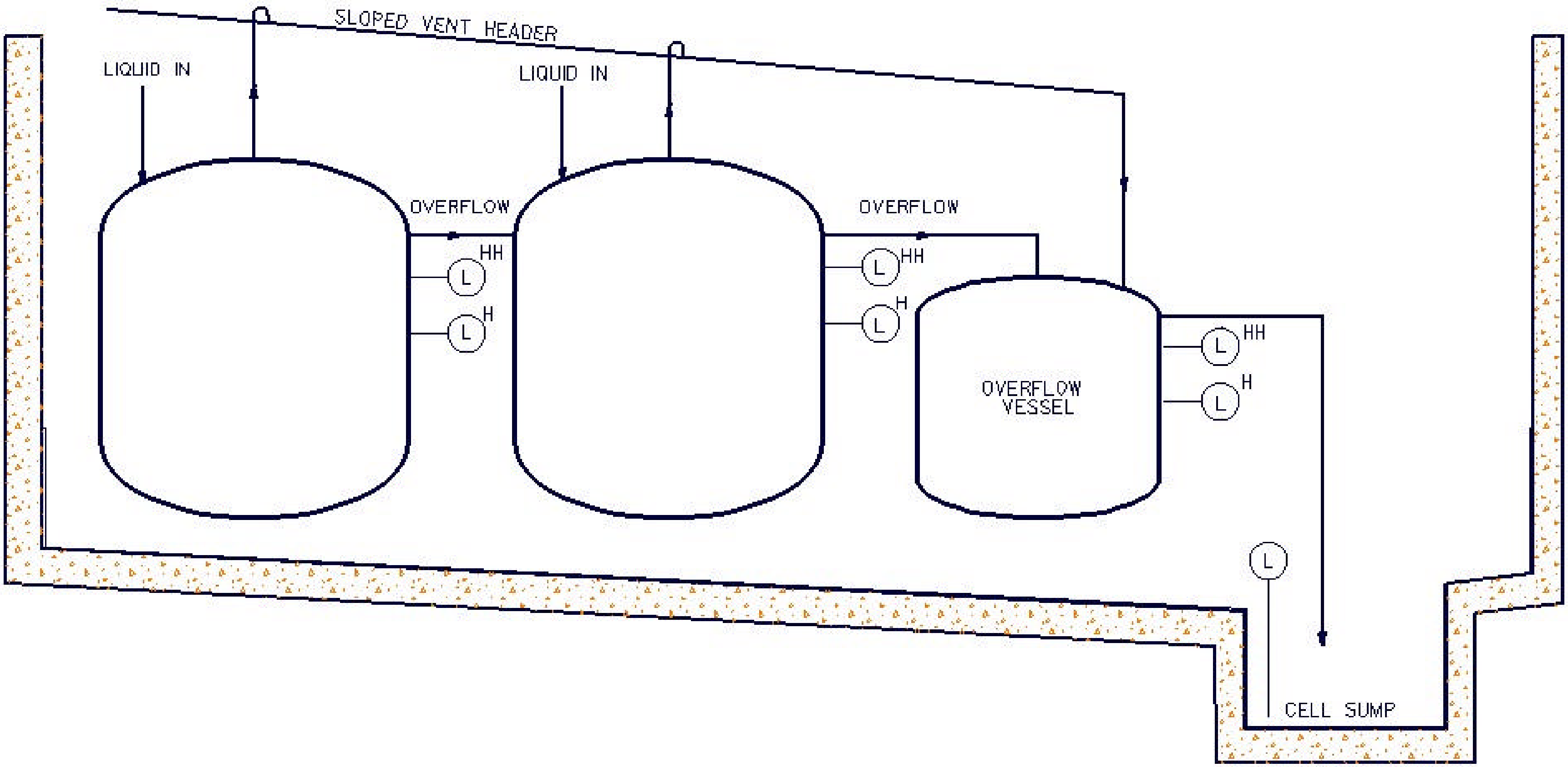


Table 2.1-1. Vessels (Containing Hazardous/Radioactive Materials)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of confinement due to breach in cell resulting in a challenge to the ventilation systems	Vessel	Contain the process fluid without loss of primary confinement	Vessel integrity Design codes Use of Suitably Qualified Emergency People (SQEP) in design/configuration Seismic design In service inspections/corrosion monitoring Material selection NDT/inspection/QA during design and construction High integrity welds, minimize mechanical connections and need for seals – typically fully welded 100% NDT in-cell Corrosion allowance/wall thickness Vessel supports – won't float if cell flooded. Overflow condition - Collection tank with level monitoring may be provided – vessel will alarm on overflow – alarms tested
Loss of confinement due to overfilling of vessel resulting in challenge to the ventilation systems	Tank level measurement Dip tube and Transducer	Provide alarm to alert operators of high level and trip alarms and stops associated transfer devices feeding the vessel	Simple proven technology Trouble alarm UPS
	Overflow piping, either dedicated, or through vessel vent piping and upstand to vessel vent drain manifold	Prevent liquor from reaching passive ventilation system and spilling to cell by routing to selected overflow vessel	Overflow is sized to handle maximum feed to tank plus margin See in-cell piping integrity
	Overflow collection tank	Maintain primary confinement	See vessel DSFs above
	Overflow collection tank level measurement Dip tube and Transducer	Provide alarm to alert operators of high level and trip alarms and stops associated transfer device(s) feeding vessels connected to the overflow collection tank	Simple proven technology Trouble alarm UPS

Table 2.1-1. Vessels (Containing Hazardous/Radioactive Materials)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
	Instrument air supply (support service)	Provide instrument air to support operation of the level instrumentation	Bottle backed See Section 2.5.1, Compressed/Instrument Air
	Overflow piping to cell sump from overflow collection tank	Route overflow from overflow collection tank to cell sump	See section 2.1.2, Piping for overflow piping DSFs
Loss of primary confinement due to leak or overflow to cell resulting in challenge to the ventilation systems	Cell liner	Maintain secondary confinement	Integrity: Material selection (compatible with process liquors) Use of SQEP in design/configuration Welding performed by qualified welders working to approved procedures Testing: Visual Dye penetrant Vacuum box I Ferrite meter Ultrasonic Radiographic Copper test Pneumatic pressure Ponding test Height of liner sufficient volume to contain the volume of the largest vessel plus margin
	Sump (wet)	Collect liquid	Liner integrity Administrative controls to check sump liquid level and sample sump contents Sump emptying ejector and pipework
	Sump level instrumentation Dip tube Transducer	Detect high level	Simple proven technology Trouble alarm UPS

Table 2.1-1. Vessels (Containing Hazardous/Radioactive Materials)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
	Alarm	Notify operator of sump high level	UPS
	Instrument air supply (support service)	Provide instrument air to support level measurement	Bottle backed See Section 2.5.1, Compressed/Instrument Air
Loss of liquid to cell resulting in challenge to the ventilation systems	C5 ventilation system	Maintain secondary confinement	See section 2.2.1 Process Building Ventilation Systems Defense in depth: Radiation monitors in cell ventilation ductwork will detect and alarm higher than normal levels

2.1.2. Piping

2.1.2.1. Purpose

The purpose of piping systems is to contain and transfer the process fluids/gases/solids between unit processes. Pipe work also aids to a certain extent in shielding, if radiation-emitting fluids/gases are being transferred.

Certain configurations of pipe work systems are also used to provide confinement protection to vessels systems.

2.1.2.2. Description

In Cell Piping

Pipe work systems are used extensively within process facilities as primary confinement of fluid/gases and for certain applications to transfer dry and wet solids. Radioactive process cells where equipment is usually designed for little or no maintenance over the life of the facility; pipework systems are high integrity. As was for the case of vessels BNFL has produced a piping design manual which identifies a set of piping groups to cover all piping used in BNFL Nuclear Chemical Plants.

Purpose of pipe groupings constitutes an authoritative design philosophy which ensures:

- The design standards are consistent with the safety and commercial considerations; in particular they ensure that the integrity level of design of the piping is related to the potential hazard involved.
- The uniformity of design and enables the economic benefits of standardization to be achieved.
- To enable design justification reports to be prepared so that authorizing authorities can simulate the design intent philosophy.
- To facilitate the specification of administrative documentation and procedures (e.g. Quality Assurance procedures) appropriate to each piping group.

Criteria for Pipe Groups

The establishment of the piping design manuals and piping design groups constitutes an authoritative design philosophy ensuring:

- The design standards are always consistent with the safety and commercial considerations; in particular, ensure that the level of integrity of the design of piping is related to the potential hazard involved.
- To ensure uniformity of design to enable the economic benefits of standardization to be achieved.
- To enable justification reports to be prepared so that authorizing authorities can readily simulate the design intent.

- To facilitate the specification of administrative documentation and procedures (e.g. Quality Assurance procedures) appropriate to each piping group.

Design Manuals

Choice of design code – ASME B31.3 Code for Pressure Piping covers the design of pipe work for differing classes or categories of integrity. The design manual is used to supplement ASME B31.3 to ensure that the piping design meets the reliability required for BNFL Nuclear Chemical Plants.

Material Selection

Pipeline material specifications are currently being prepared for TWRS-P based on both BNFL and US experience. Each pipeline will be individually evaluated using Pipeline Material Specification questionnaires that identify the pipe operating parameters:

- Fluid
- Pipe size
- Activity
- Radiological zoning
- Contamination zoning
- Maximum credible temperature
- Maximum credible pressure
- Operating environment

These parameters are used by the pipeline material specification section to ensure that the correct pipe specification is selected. The specification will also identify all pipeline fittings that can be used in pipelines covered by that specification

Non-Destructive Testing of Pipelines

The pipeline duty will govern the degree of radiography required. The general rule is that all flooded active pipework will be radiographed. A senior pipe designer will review each pipeline to determine the degree of radiographing that is required using guidelines identified in the design manual.

All butt welds in pipeline and supports for pipelines shall be examined by a surface crack detection method usually dye penetrant.

Out-Cell Piping

Normal practice for out-cell pipework carrying hazardous fluids is to where possible have all welded joints and keep flanged or screwed connections to a minimum. Where these types of joints have to occur it is preferable to have these connections totally enclosed. For instance, if the connections were to a plant wash glove box or cabinet, then the connections would be within the cabinet providing total confinement.

Where total confinement is not practicable, for instance, flanged connections to pumps or heat exchangers, flange splashguards are utilized and potential spills are directed to drip trays. When a number of systems carrying hazardous reagents can be grouped within a room or reagent berm, then the berm would be stainless steel clad and have its own sump to direct spills to a dump tank. Flanges would still utilize flange guards for personnel and equipment protection.

Pipework systems carrying steam, whether HP or LP, or hot water are always lagged for personnel protection. This also has the effect of acting as a flange guard for potential leaks. If problems are experienced with flanges leaking on steam systems due to thermal cycling when steam is energized and de-energized on a frequent basis then live loading of flanges is utilized to prevent these leaks. It is not normal practice to provide drip trays for flanged joints on steam or water systems.

In all cases pipework, whether out-cell or in-cell, is supported by pipe supports to ensure the pipes are not subject to undue stress.

Gaskets are chosen for compatibility with the fluid being transported and the pipe material. Where possible the types of gaskets are minimized, for example if possible there would be one type of gasket for chemical applications and one gasket for high temperature applications. The gasket is constructed in such a way that it is compatible for all flange pressure classes for a particular pipe bore diameter. To complement this the flanges would be color-coded for easy identification when fitted into a line. (The steel-trap gasket is an example of such a gasket.) This approach is an attempt to minimize the change of a gasket of the wrong material being fitted within a pipework system.

Training is given to all personnel involved in gasket replacement including identification and fitting of gaskets, and bolting as well as their suitability for various applications.

2.1.2.3. Hazardous Situations

Hazards are typically loss of confinement, either in cell or out cell. Loss of confinement in-cell, while not typically immediately posing a hazard to the worker, does pose challenges in terms of recovery, requiring special procedures and imposing increased radiation hazards. Loss of confinement in-cell also places demands on other safety systems e.g. sumps/drainage /decontamination systems, ventilation systems etc.

Loss of confinement of a pipe (containing radioactive process fluids/gases) out-cell poses a greater hazard to the worker and hence the need for secondary confinement and leakage monitoring.

Table 2.1-2. Piping (Containing Hazardous/Radioactive Materials)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of confinement – breach in cell/cave	Piping	Contain the process fluid	Corrosion allowance/wall thickness 100% NDT/inspection/QA during design and construction Use of SQEP in design/configuration Material selection In service inspections Seismic design Startup testing to verify routing etc. For cells that are inaccessible to personnel, pipe work is typically fully welded i.e. no mechanical connections
Leak from primary confinement pipe in a coaxial pipe system	Piping	Contain the process fluid	Corrosion allowance/wall thickness 100% NDT/inspection/QA during design and construction Use of SQEP in design/configuration Material selection In service inspections Seismic design Startup testing to verify routing etc. For cells that are inaccessible to personnel, pipe work is typically fully welded i.e. no mechanical connections
	Leak detection equipment for coaxial piping (pipe-in-pipe) systems	Alert operators of pipe leak	Simple design (conductivity probe)
	Outer pipe for coaxial piping (pipe-in-pipe) systems	Provides secondary confinement	See piping DSFs above to contain process fluid Engineered for drainage collection of any leakage
	Catchment pot	Maintain confinement and houses leak detection system	Welded Tee (passive)
	Leak detection (conductivity high switch)	Provide alarm to alert operators of pipe leak in coaxial pipe	Trouble alarm UPS
	Local/area radiation monitors	Detect/alarm on high radiation	Trouble Alarm UPS

Table 2.1-2. Piping (Containing Hazardous/Radioactive Materials)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of confinement out of cell for non-radioactive hazards	Piping	Maintain confinement of hazardous material	See piping confinement DSFs above
	Drip trays	Maintain secondary confinement (prevent spread of hazardous materials)	See piping confinement DSFs above
	Hazardous material monitors	Detect and alarm to alert operators of hazardous material leakage	Trouble alarm UPS

2.1.3. Cells and Caves

2.1.3.1. Purpose

Provide secondary confinement and provide radiological protection to personnel for process and mechanical handling unit operations.

2.1.3.2. Description

Cells

Cells are typically constructed from thick concrete walls that provide radiological protection to the facility personnel. Cells house process equipment and pipework that are designed to be low maintenance for the duration of the plant life. Cell access is not provided during normal radioactive operations.

Cell floors and walls up to height sufficient to contain the contents of the largest vessels including a margin are lined with stainless steel. The slope on the floor cladding will direct the liquor to a sump installed with leak detection. The liquor can be removed by steam ejectors for analysis and storage. Cladding decontamination can be performed by washing the cladding with clean water and/or approved detergent.

Specification for materials used for stainless steel cladding have been developed based on extensive experience gained in cladding process cells on many projects. Specified tolerances for materials along with welding and weld test procedures ensure quality of the secondary confinement provided by the cladding. All welded seams are examined to ensure they are free of unacceptable defects. Listed below are some of the tests performed:

- Visual inspection
- Dye penetrant examination
- Ferrite meter check
- Ultrasonic examination
- Radiographic examination
- Copper tests
- Pneumatic pressure test
- Ponding test

Before welding can proceed each welder is approved to the relevant approved welding procedure.

To provide maximize confinement by the cell structure, penetrations through the cell wall will have a shielding assessment performed to determine the amount of radiation shine occurring through each penetration. Wall boxes are used to pass process lines, inactive services, and instrument lines (into caves, electrical cabling). Depending on the bulk activity contained within the process vessels the wall box design could either be of the joggled or straight through type. If the activity is high the shine path of a straight through wall box may be unacceptable. In such cases, the pipe is bent or joggled to interrupt the shine path and where necessary, infilled with concrete of higher density than the cell wall to make good any shielding deficiency.

In case of through wall plugs, e.g., for TV inspection or through wall drives, shine paths are eliminated by stepping the plug or the sleeves of the through wall drive.

The purpose of wall boxes is to allow pipework to penetrate the walls, floors or roof of cells, but in doing so they create leak paths within the annules of the primary and sheath pipes where air can pass from the inside to outside of the cell. As there are significant numbers of pipe penetrations within cells it is essential to seal these leak paths by the use of packed glands, compression seals or seal washers.

A typical process cell is shown in Figure 2.1-2.

Caves

Caves are also typically constructed from thick concrete walls that provide radiological protection to the facility personnel. In general, caves house mechanical handling equipment designed for remote operation, although limited hands on maintenance may be permitted. Cave wall penetrations are similar to those described for cells. Caves generally have sealed lead glass viewing windows to allow observation of the cave operations and are needed for the remote maintenance. The windows also allow for observation of faults. Figure 2.1-3 shows a cave layout containing remote operation.

Cell/caves rely on an active ventilation system to maintain the confinement since some penetrations in the concrete structure cannot be hermetically sealed e.g. drive shaft penetration for shield doors. The ventilation system ensures an adequate inflow of air from the out cell areas to maintain confinement. Vessel ventilation provides a cascade ventilation system ensuring the flow of air is always from areas of lesser contamination to areas of higher contamination.

Building

The building houses the cells and caves and is important to safety. It will be designed to ensure that it can withstand all loads imposed by equipment and other natural phenomena hazards and external events, as discussed in Section 2.10**.** C2 ventilation would ensure the airflow would always be in the building.

2.1.3.3. Hazardous Situations

Hazards associated with cells/caves include unauthorized removal of wallplugs and through wall drives and drop loads carrying potential damage to secondary confinement.

The set of Important to Safety SSCs for the above hazardous situations (or faults) is provided in the following tables. The tables also identify the Safety Functions and the Design Safety Features.

Figure 2.1-2. Typical Process Cell

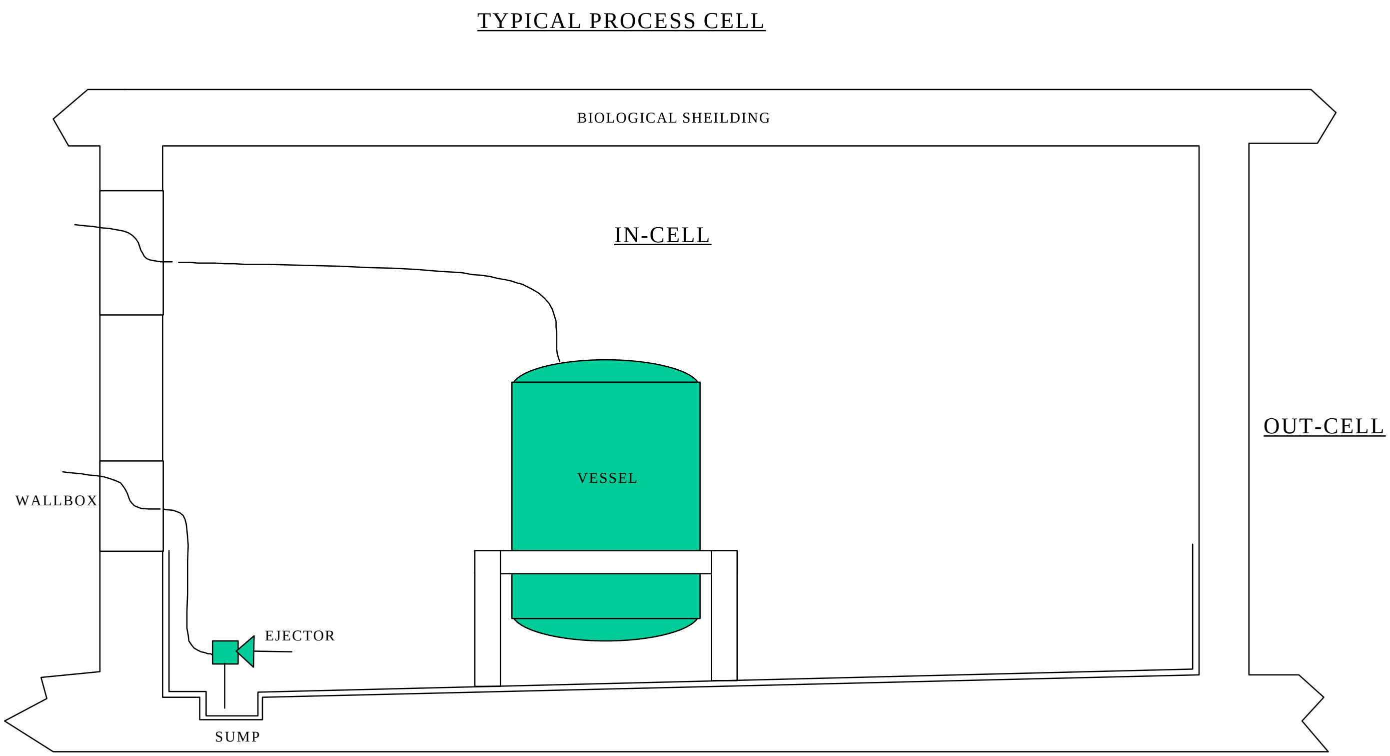


Figure 2.1-3. Typical Cave Layout for Remote Operations

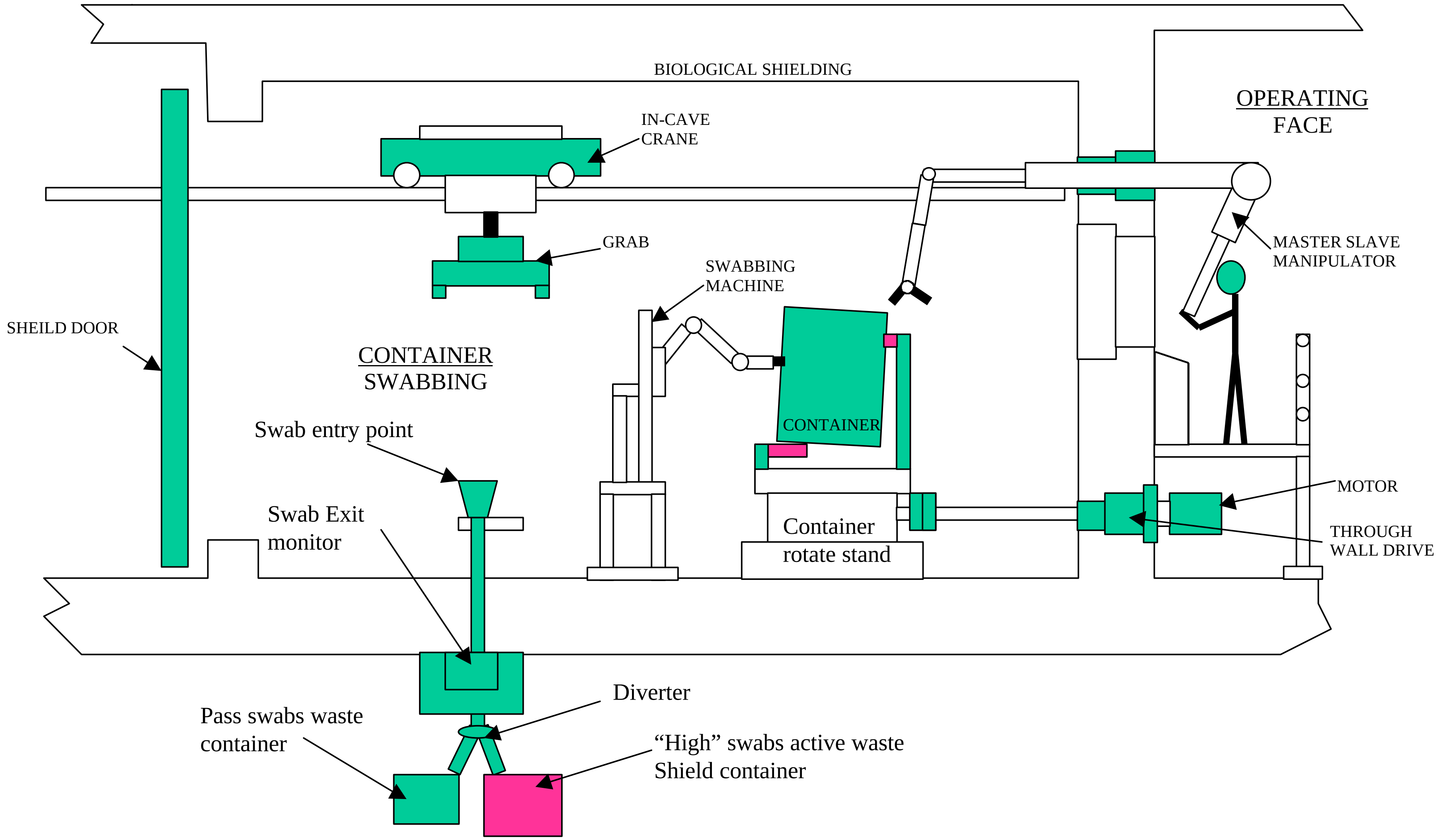


Table 2.1-3. Cells and Caves

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of secondary confinement – unplanned/uncontrolled removal of a through wall shield plug/drive etc.	Wall plug.	To provide an adequate seal between the cell/cave and the surrounding personnel access area	Dedicated special removal equipment and strict admin control is needed to remove plugs from cell/cave Cells/caves designed to withstand DBEs e.g. seismic
	Cave/cell ventilation	To maintain pressure differential and flow of air from the personnel access area into the cell/cave under confinement breach conditions, thus minimizing dose uptake to a worker	C5 vent system is in place to ensure pressure differentials are maintained between out cell and in cell areas. See Section 2.2.1
Breach of confinement due to drop load impact from out-cell areas	Cell/cave roof construction	To provide secondary confinement under normal and identified off-normal/ accident conditions	Cell/cave roof structure designed to withstand all identified drop loads or suitable shock absorbing medium within cave/cell roof is utilized
Inadequate shielding	Cell/cave wall	Provide shielding	Design codes Use of SQEP in design/configuration Seismic design Material selection NDT/inspection/QA during design and construction Shielding assessment Designed to withstand maximum cell temperature Analytical assessment of structural stability

2.1.4. Gloveboxes

2.1.4.1. Purpose

The purpose of a glove box is to provide a total enclosure, with facilities for gloved hand entry, in which material may be manipulated in isolation from the operator's environment.

2.1.4.2. Description

Gloveboxes used in radioactive environments are typically constructed of stainless steel, and allow operator access to materials that present inhalation or skin contamination. They are fitted with glove ports and windows to facilitate manipulation of equipment containing the hazardous materials while the operator views through windows fitted in the shell of the glovebox. The glovebox shell is a passive design safety feature.

Gloveboxes are constructed to varying integrity classes, dependant on a number of factors determined during the hazard analysis at the design stage. The glovebox enclosure is providing primary confinement (e.g., used in analytical chemistry, or where a primary confinement system within the glove box could be breached for hands-on maintenance), the integrity of the glovebox shell and all penetrations must assure that a leak rate allowance into the enclosure shall be no greater than 0.05% of the box volume per hour.

Where the glovebox shell is providing secondary confinement, and the possibility of it becoming primary confinement is considered unlikely by a hazard analysis, then a leak rate allowance into the enclosure not exceeding 0.5% of the box volume/hr may be specified.

Penetrations for services into the enclosure are required to equal or exceed the integrity class to ensure that confinement is not breached. Electrical and instrument penetrations use plug/sockets to ensure no leak paths through the cables.

Gloveboxes may be shielded, if required by the results of a shielding analysis and ALARA assessments.

The glovebox atmosphere is maintained at a negative pressure relative to the external surroundings. If a breach occurred, flow would be achieved through the breach and into the ventilation system.

Gloveboxes are typically connected to a ventilation exhaust system. Primary and secondary HEPA filters are provided to ensure adequate treatment, prior to discharge to the facility stack. Local HEPA filtration may be provided to limit carry over of contaminants into the ventilation pipe work. Some glovebox applications (where airborne radioactivity e.g. alpha is present) are fitted with an emergency exhaust. The emergency exhaust is fitted with a fail-safe valve that opens on loss of negative pressure within the glovebox (e.g. a torn glove), which increases the flows and velocity across the breach to protect against migration of contaminants into the operator area. A vortex amplifier system is sometimes utilized to maintain a negative pressure within the glovebox. The vortex amplifier is high reliability fluidic device, with no moving parts in contact with the glovebox atmosphere (as opposed to a fail-safe mechanical valve). It is designed to throttle the ventilation exhaust, and maintain an adequate vacuum within the glove box under normal operating and emergency (breach) flow conditions.

The glovebox ventilation supply may be a piped system (e.g., if inert gases are used for the glovebox atmosphere) or may be drawn in from the room. Over pressurization protection is provided by a HEPA filter or back flow damper in the supply connection.

Gloveboxes that contain “wet” processes are typically fitted with sumps and drainage systems, and with sump level detection equipment.

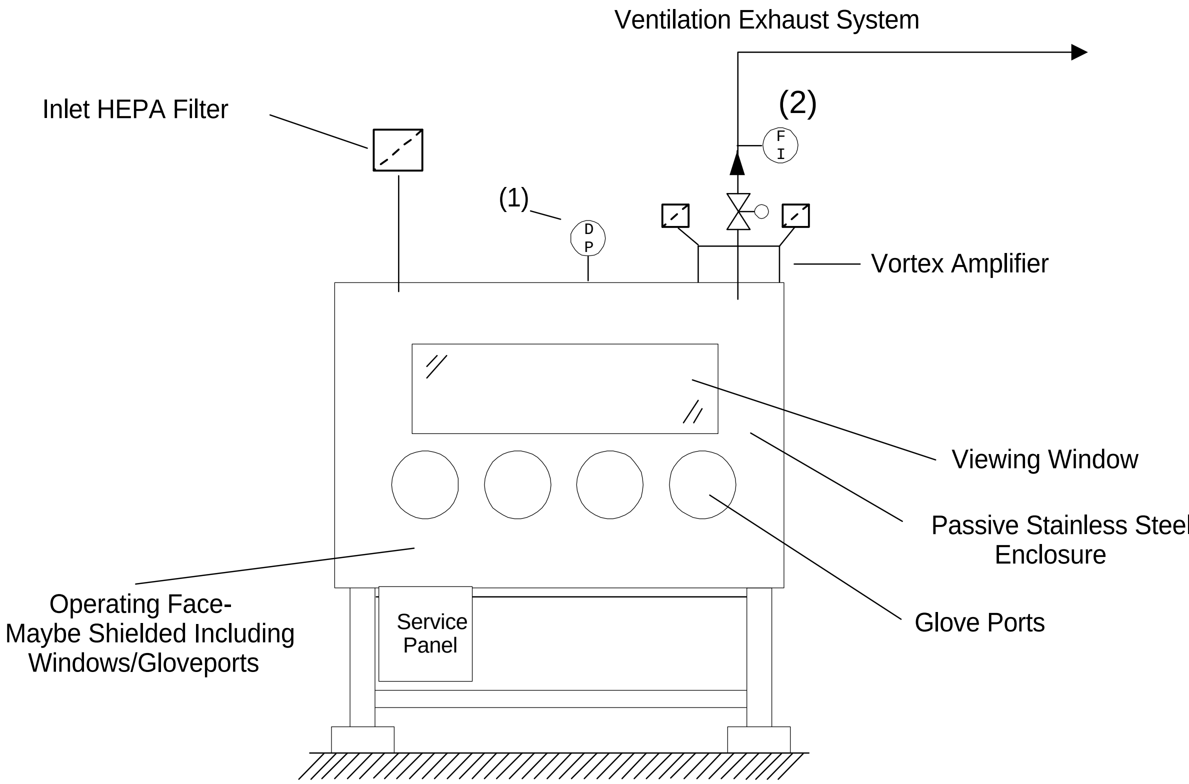
See Figure 2.1-4 for typical glovebox features.

2.1.4.3. Hazardous Situations

Hazards associated with gloveboxes are typically associated with excursions of contaminants into the breathing zone of the operator from unplanned breaches in the confinement e.g. tear in a glove. The integrity of the glovebox structure is critical to protect the operator, supplemented by special ventilation design safety features, as discussed in the attached table.

The set of Important to Safety SSCs for the above hazardous situations (or faults) is provided in the following tables. The tables also identify Safety Functions and the Design Safety Functions.

Figure 2.1-4. Typical Glovebox Features



(1) Local Pressure Gage/ Displays negative pressure in glovebox relative to room

(2) Flow indication / Alarm may be provided

Table 2.1-4. Gloveboxes

Fault	Important to Safety	Safety Function	Design Safety Features
Loss of confinement due to failure of glovebox structure	Glovebox structure	Maintains integrity and confines inventory	Glovebox designed as rigid body to withstand DBE and maintain integrity – seismic modeling performed during design. Glovebox shell is passive Extensive inspection, testing and quality control of materials, construction methods. Leak testing during construction and installation
Loss of confinement due to through wall equipment seal failure; glove/bag rupture	Glovebox Ventilation system	Maintains airflow into the glovebox to minimize potential spread of inventory to surrounding area	Glovebox is typically vented through to cell area (C5 extract) via straight pipe See C5 Extract, Section 2.2.1, Process Building Ventilation Systems.
	Flow regulating device in glovebox vent (e.g. Donkin valve, Vortex Amplifier)	Provide satisfactory depression under normal operations and required airflow under fault conditions	Simple devices
	Seals and penetrations	Maintain glovebox integrity	Through wall mechanical equipment typically has double seals Administrative control of the replacement of gloves/bags Strict procedural control is in place during “in-glove” operations; e.g., local contamination monitoring and inspection of the gloves Special purpose glove/port and bag/port designs reduce potential of migration of contamination during glove use/change and bagging operations Bag less transfer devices, (that preclude the use of a bag and therefore reduce the potential for contamination migration) are used in certain applications Glovebox internals are designed such that no sharp edges are present to reduce potential for torn gloves and therefore breach of confinement.

Table 2.1-4. Gloveboxes

Fault	Important to Safety	Safety Function	Design Safety Features
	Local area Monitor/Alarm	Notify operator of high airborne contamination levels	Continuous Air Monitor Trouble Alarm Battery Back Visual and Audible Alarm
Pressurization leading to potential migration of contamination from the glovebox	Glovebox Ventilation system	Maintains adequate negative pressure/flow	Glovebox is typically vented to cell area (C5 extract) via straight pipe See C5 Extract under Ventilation
	Glovebox structure	Provides primary confinement in the event of a ventilation system failure	Glovebox Integrity (see above) Local pressure gauge monitors and displays negative pressure within the glovebox. This gauge is checked frequently Alarm on loss of safety function (pressurization)
Leakage of radioactive/hazardous fluids from equipment within the glovebox	Glovebox structure	High integrity structure prevents leaks	Glovebox Integrity (see above) Leak tested during construction and installation
	Glovebox drainage system	Provides drainage to prevent unnecessary buildup within the confinement	Drain sized to discharge maximum flow condition Glovebox sump contains liquid detection instrumentation

2.1.5. Remotely Maintainable Pumps

2.1.5.1. Purpose

Mechanical pumps are used within the TWRS facility for both out cell and in cell duties. Within active process areas, the use of maintenance free transfer devices are used in preference to mechanical pumps. However, where there are requirements for high flow (i.e., through the evaporator circuits) and high head (i.e., pumping active liquor within an ultrafilter circuit), duties can only be provided by a mechanical pump.

Mechanical (centrifugal) pumps are installed in-cells or bulges (i.e., C4 or C5 areas) where fluid flow or discharge pressure requirements preclude the use of less complex equipment. The pump casing design allows pump removal without loss of cell confinement. In situ decontamination of mechanical pumps is difficult due to the pump internals and larger plate-out areas. However, use of mechanical pumps may not be an option for some high activity streams. Remotely maintainable pumps may be repaired locally, in a remote in-cell facility, or disposed in a waste container and replaced by a new unit.

2.1.5.2. Description

For process duties, the mechanical pump and associated valves will be controlled by the Distributed Control System (DCS) for normal operating sequences. Where off-normal conditions can occur, an alarm and trip of the transfer device will be provided. The pump system is designed to allow drainage of active liquid from the pump. At the end of transfers, in addition, there is the capability to introduce flush liquids to reduce residual contamination.

For out-cell service duties, mechanical pumps will have the same control features as for active duties. The pump flowrate is usually monitored since the out-cell pump duties have potential impact on the control of process operating conditions.

Mechanical pumps within the facility will be designed to be maintainable. The type of pump mechanism normally used for remotely maintainable pumps is centrifugal radial. However, this does not preclude the use of an alternative type of pump. As an example, high flows and low differential pressures associated with evaporator recirculation pumps indicate the use of centrifugal axial types. The centrifugal axial type pump construction is in a cartridge form that can be withdrawn from the welded-in fixed outer casing.

Remotely maintainable pumps can be installed either in-cell or in a bulge. The pump arrangement incorporates two confinement barriers between the pumped fluid and the operating area. The interspace between these barriers, which is formed by the fixed outer casing, is provided with a combined overflow and vent connection.

The first confinement barrier is between the pump wet end and the interspace and is provided by a double mechanical seal. If this seal should fail, the leakage is drained by the fixed casing overflow and vent connection to a central leak detection point so that decommissioning and repair or replacement can be initiated. The overflow, in addition to providing pump failure detection, prevents pressurization of the fixed outer casing up to the sealed connection at the top in the operating area and assists ventilation during cartridge withdrawal activities.

The second confinement barrier is provided by the top flange of the pump assembly that incorporates the upper seals. A biological shield is provided adjacent to the top flange. The pump unit is built into a cartridge assembly which is removable for maintenance or replacement. The cartridge is withdrawn from the fixed outer casing into a glovebox for local maintenance or via gamma gates into a shielded flask for transport to a remote facility. To assist in the prevention of activity release during flasking operations, a temporary connection to the C3 vent system is required. Equipment can be provided for remote in-cave decontamination, strip down, repair, and re-assembly prior to return to service. To ease maintenance tasks, individual components such as mechanical seals, are provided in cartridge form pre-set in the workshop.

Figure 2.1-5 indicates the main components and operating philosophy.

2.1.5.3. Leak Detection

Pumps conveying fluids with similar activity values and compatible chemical characteristics can share common leak detection facilities. To determine which of the pumps has failed for shared systems, it is normal to provide an intrascope access hole in the biological shield, which is fitted with a removable plug. Provisions for leak detection are similar to those used on remotely maintainable valves. See Figure 2.1-6 for typical leak detection system configuration.

2.1.5.4. Hazardous Situations

Hazards associated with liquid transfer are as follows:

1. Overpressurization of the pump circuit causing breach of confinement.
2. Excessive flow causing flooding of process equipment.
3. Overfilling of recipient vessel.
4. Loss of service flow.

Hazards associated with confinement/shielding of the remotely maintainable pumps are:

1. Loss of confinement/shielding due to seal failure, or
2. Unplanned/unauthorized removal of the pump/shield plug assembly.

If the seals on the pump and at the biological shielding were to fail, there is a potential for contamination to migrate from the primary or secondary confinement into the operator areas.

Special purpose removal equipment in the form of a flask/gamma gate system is required to safely remove the pump assembly for maintenance/replacement. Strict administrative procedure and controls must be in place to ensure that only the correct equipment and support facilities are used.

The set of Important to Safety SSCs for the above hazardous situation or Faults is provided in the following tables. The tables also identify the Safety Function and the Design Safety Function.

Figure 2.1-5. Typical Remotely Maintainable Pump

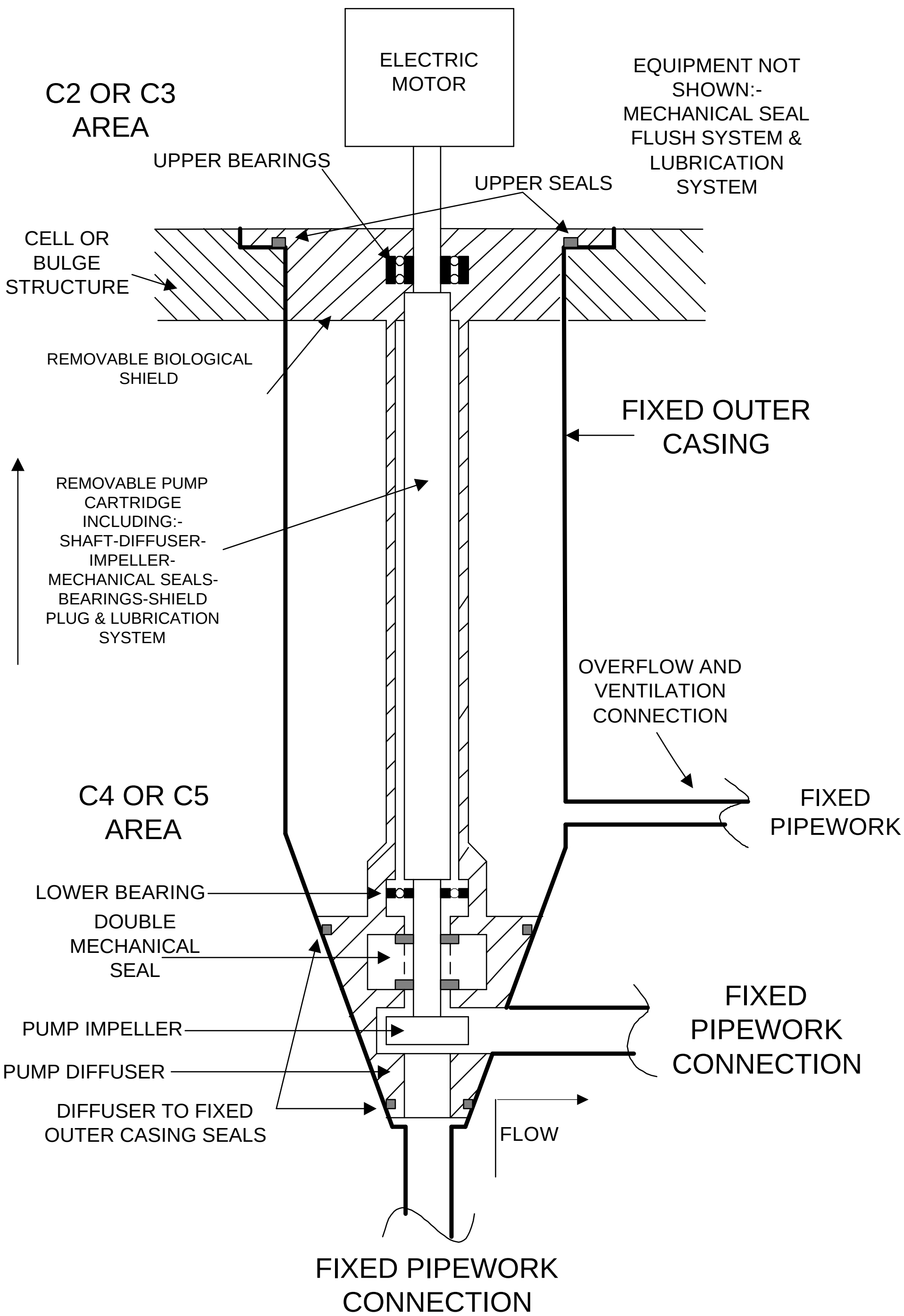


Figure 2.1-6. Typical Remotely Maintainable Pump Leak Detection System

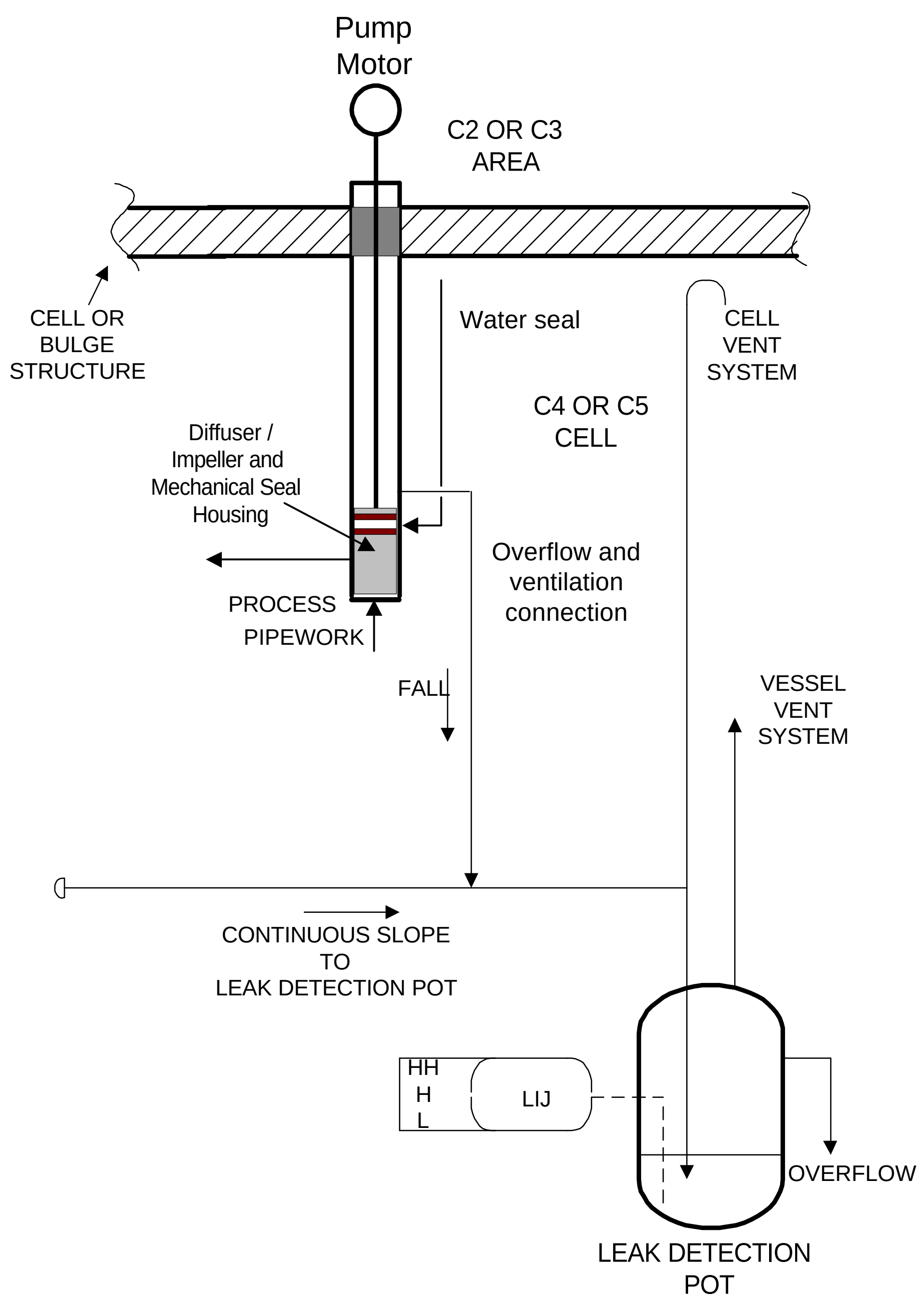


Table 2.1-5. Remotely Maintainable Pumps

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of primary confinement due to pump seal failure	Pump seal	To provide primary confinement of pump/pipe system	Multiple seals protecting pump drive and impeller. Seals between the cell roof and the shield plug integral to the pump High pressure water in seal interspace which is monitored for leakage Material selection In service inspections High integrity seals
	Overflow	Engineered route for recovery of leak process fluids	Drainage route from outer casing to a leak detection system (vessel and instrument) to detect leak.
Loss of cell secondary confinement due to requirement for pump maintenance	Pump outer casing/seal assembly	To provide cell confinement	Pump casing design enables pump removal without breach of cell confinement Seals between casing and through the roof liner protect confinement
No flow resulting in the onset of an off normal event	Flow Instrumentation	To detect low or no flow	Duplicate standby pump energized on no or low flow

2.1.6. Remotely Maintainable Valves

2.1.6.1. Purpose

Maintainable valves are used either in-cell or in bulges based on process requirements. Remotely maintainable valves are fitted to in-cell pipelines (C4 or C5 areas) for flow isolation or control purposes. Their construction allows removal without loss of cell confinement to either a local glove box or remote maintenance facility depending on plate-out activity following in-situ decontamination. Out-cell conventional valves are used to control and isolate service, utility, and cold chemical supplies to the process.

2.1.6.2. Description

Valves are used throughout the facility. For in-cell applications, non-maintainable alternatives to valves are generally selected. However, certain are process operations require the application of maintainable valves (i.e., multicolumn ion exchange operations, ultrafiltration and evaporator operations). The mechanism normally used on remotely maintainable valves is a rotary plug. This type of valve is available in a form that allows removal of all the internals in a single operation including the seat from the welded, in-body, and simplifies replacement.

Other types of valve mechanisms can and have been used for remotely maintainable duties which can be adopted if use of a plug type valve is not considered appropriate for the process conditions. An important consideration in the selection of the valve must be the avoidance of cavities that can trap contaminants.

The remotely maintainable valve arrangement comprises two confinement barriers separating the pipe contents from the operating area. The inter space confinement between these barriers is provided with a combined overflow and vent pipe.

Leakage from the first confinement barrier is prevented by two separate sealing arrangements, which are part of the taper plug valve assembly. If both seals fail, leakage is drained via the fixed outer casing overflow pipe to a central leak detection point to allow maintenance. The overflow route also prevents pressurization of the fixed outer casing up to the flanged connection on the outside of the biological shielding.

The top flange of the remotely maintainable valve assembly incorporates the upper seals forming. The second confinement barrier is provided by the top flange of the remotely maintainable valve assembly that incorporates upper seals. A biological shield is also provided adjacent to the top flange.

The taper plug valve is built into a cartridge assembly, which is removable for maintenance or replacement. The valve internals are removed from the fixed outer casing either into a glovebox for local maintenance or via gamma gates into a shielded flask for transport to a remote facility. Equipment can be provided for replacing both the plug and cartridge sleeves remotely. See Figure 2.1-7 for typical remotely maintainable valve details.

2.1.6.3. Leak Detection

Valves conveying fluids with similar activity values and compatible chemical characteristics can share common leak detection facilities. To determine which of the valves has failed, for shared systems, it is normal to provide an intrascope access hole in the biological shield, which is fitted with a removable plug. See Figure 2.1-8 for typical leak detection system configuration.

2.1.6.4. Hazardous Situations

Potential hazards associated with process liquid diversion or isolation include the following:

1. Mis-routing of liquids
2. Backflow of activity into operating areas.
3. Overfilling of vessels
4. Loss of services

Hazards associated with confinement/shielding of the remotely maintainable valves are:

1. Loss of confinement/shielding due to seal failure, or
2. Unplanned/unauthorized removal of the valve/shield plug assembly.

If the seals on the valve and at the biological shielding were to fail, there is a potential for contamination to migrate from the primary or secondary confinement into the operator areas.

Special purpose removal equipment, in the form of a flask/gamma gate system, is required to safely remove the valve assembly for maintenance/replacement. Strict administrative procedure and controls must be in place to ensure that only the correct equipment and support facilities are used.

The set of Important to Safety SSCs for the above hazardous situations (or Faults) is provided in the following tables. The tables also identify the Safety Function and the Design Safety Functions.

Figure 2.1-7. Remotely Maintainable Plug Valve (2 or 3 Way)

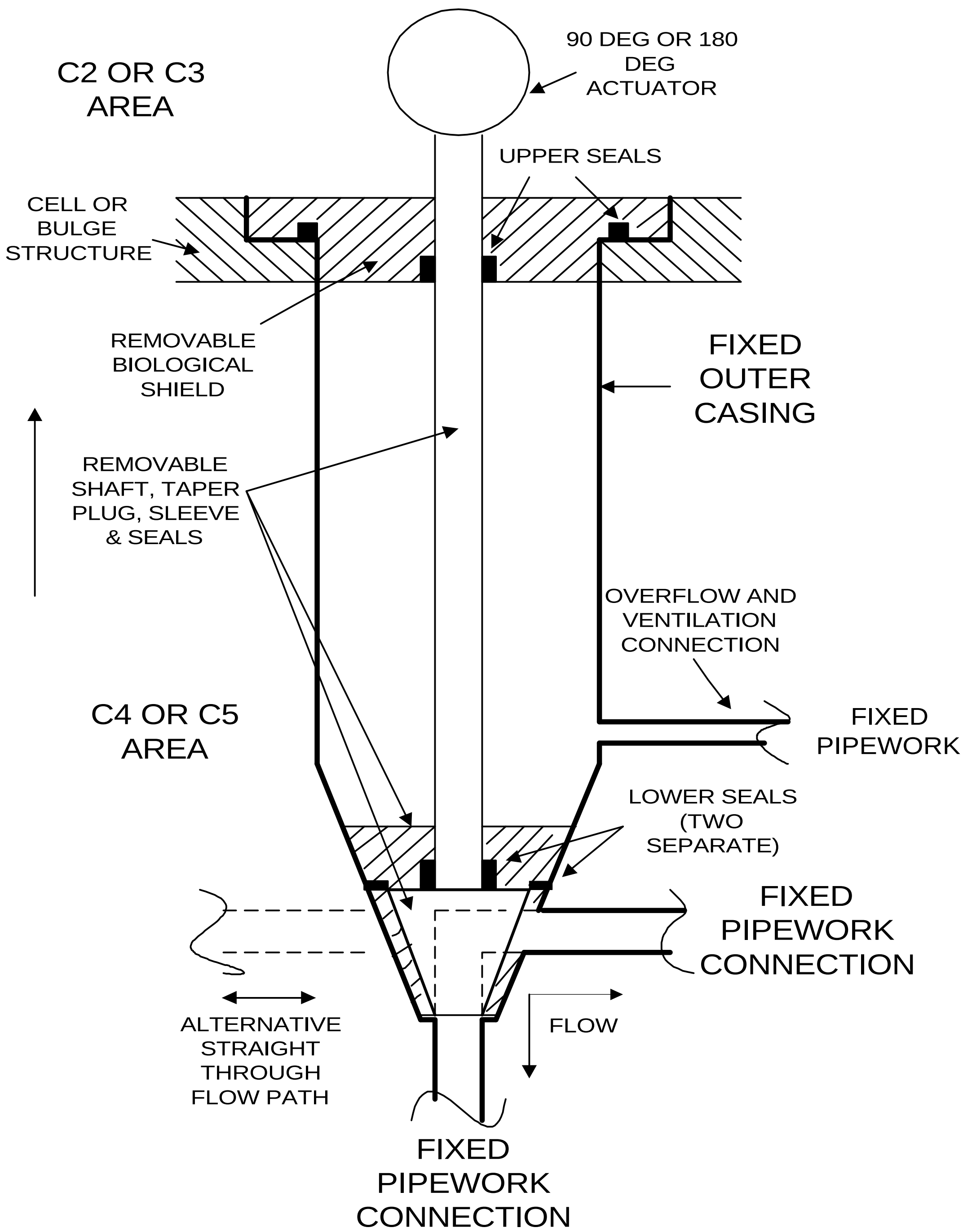


Figure 2.1-8. Typical Remotely Maintainable Valve Leak Detection System

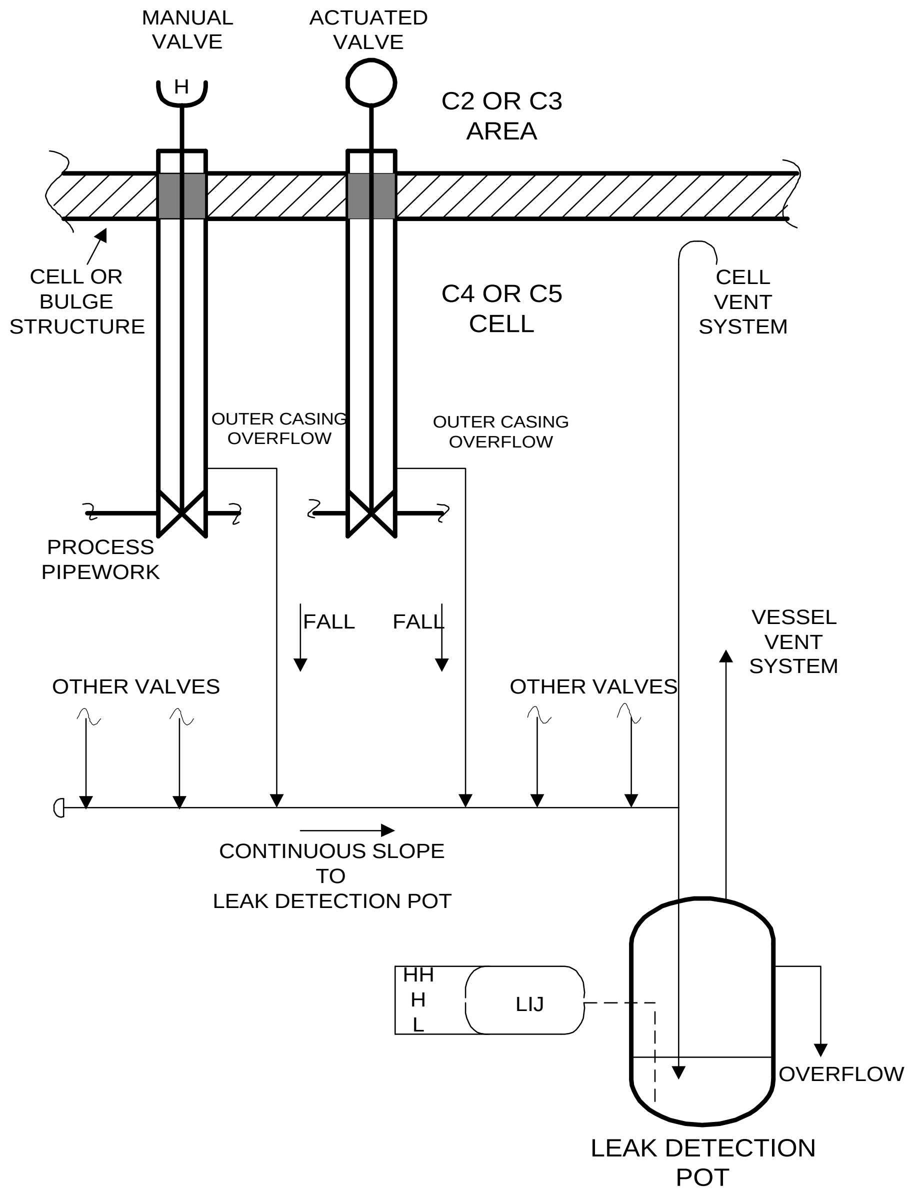


Table 2.1-6. Shielding and Confinement: Remotely Maintainable Valves

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Failure of valve, causing overfilling of downstream vessel or loss of isolation	Valve and actuator	For valve to isolate feed on demand	Actuator ensures valve fails in the closed (isolated) position
Loss of primary confinement due to valve seal failure	Valve seal	To provide primary confinement of valve system	Multiple seals protecting valve stem and plug. Seals between the cell roof and the shield plug integral to the valve Material selection In service inspections High integrity seals
	Overflow	Engineered route for recovery of leak process fluids	Drainage route from outer casing to a leak detection system (vessel, instrument) to detect leak
Loss of cell secondary confinement due to requirement for valve maintenance	Valve outer casing/seal assembly	To provide cell confinement	Valve casing design enables valve removal without breach of cell confinement. Seals between casing and through the roof liner protect confinement

2.1.7. Service Cabinets (Steam/Plant Wash)

2.1.7.1. Purpose

Service cabinets are typically provided to facilitate safe operation and maintenance of ejector steam control valves (located in steam valve cabinets) and plant wash pipe/valve distribution equipment (located in plant wash cabinets). They provide appropriate sustainable confinement for the first out cell demountable connections (e.g., flanges/valves/couplings). This is based on a design philosophy that all maintainable components of a piped system are located out–cell and components in-cell are passive (i.e., contain no moving parts) with no maintenance required.

2.1.7.2. Description

A range of "standard" cabinet designs for steam valve, plant wash, and other systems have been developed by BNFL. Service cabinets are typically located adjacent to the cell structure boundary and are stainless steel enclosures with access through doors to facilitate operations and maintenance of the internal equipment. The cabinets are ventilated, by the cell ventilation. Air from the room is drawn through louvers (i.e., engineered air gaps in the cabinet), through a HEPA filter and into a pipe which leads into the cell. The HEPA protects against migration of contamination into the out cell area in a postulated cell pressurization event. Design safety features to protect against migration of contamination from the in-cell equipment include the following: self-seal couplings (plant wash), positive vent valve systems (steam valves), lutes in-cell, cabinet sumps with drains, and sump level monitoring equipment. Certain cabinets require shielding to maintain dose uptake to the worker ALARA.

2.1.7.3. Hazardous Situations

The main hazard associated with cabinet operations is migration of contamination via the in-cell pipe work systems into the cabinet environment, and into the operating area. As described above a number of diverse design safety features are in place to reduce the potential of this event.

Where a shielded cabinet is required, the shielding is typically fixed in place (i.e., not easily removed). Operational and administrative controls are also provided to minimize the dose uptake to maintenance personnel when sections of the shielding need to be removed for access to internal equipment. Additionally, cabinets are typically located in a controlled access area (i.e., not normally occupied).

The set of Important to Safety SSCs for the above hazardous situations (or Faults) is provided in the following tables. The tables also identify the Safety Function and the Design Safety Functions.

Table 2.1-7. Service Cabinets (Steam/Plant Wash)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Release of radioactive/hazardous materials from the cabinet into a personnel access area	Cabinet structure	Aids confinement of the hazardous materials and provides a ventilated, controlled transition between the services and the process cell/cave.	Stainless steel, fully welded construction, with limited controlled access points for operations/maintenance NDT/inspection/QA during design and construction Material selection
	Valves, couplings, and connecting pipework	Provide pressure boundary for confinement	3-way self venting isolation valves Self-sealing couplings to prevent back migration of contaminants from the cell/cave. Administrative controls are in place to ensure disconnection of plant wash supply, closure of valves, doors closed and locked when cabinet not in use Cabinet location – location of cabinet is typically a barometric head above the vessel liquid level. This is checked during design and installation. Lutes in lines between cabinet and process vessel provides a hydraulic seal between the vessels, vessel vent, and cabinet vent to minimize back migration of contaminants. These lutes are filled manually periodically as an extra precaution against potential “dry out”
	Cabinet drainage systems	Reduces potential of uncontrolled release of radioactive/hazardous materials into personnel access areas	Engineered drainage system to cater for leaks within cabinet
	Cabinet extract system	Reduces potential of uncontrolled release of radioactive/hazardous materials into personnel access areas.	C3 or C5 extract system maintains negative pressure in cabinet, relative to room, thus minimizing migration of contamination out of cabinet to worker

Table 2.1-7. Service Cabinets (Steam/Plant Wash)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Unplanned exposure of a worker to radiation doses above prescribed limits	Cabinet shielding	Maintain dose uptake ALARA during normal operations and planned maintenance activities	Fixed/welded shielding is provided where determined necessary by mathematical shielding assessments Administrative controls are provided where shielding sections are to be removed to gain access to equipment for maintenance, to ensure dose uptake is maintained ALARA On unshielded cabinets, provisions are made to add shielding at a later date if radiation levels increase Radiation monitoring is in place to determine effectiveness of shielding during operations/maintenance

2.1.8. Through Wall Drives

2.1.8.1. Purpose

Through-wall drives are used to transmit power, via a mechanical drive shaft, from an electric motor mounted out-cave to a drive unit in-cave.

2.1.8.2. Description

To limit maintenance performed in-cave, all motors and gearboxes that require routine maintenance will be placed out-cell where practical. Through-wall drives consist of an electric motor and gearbox assembly that is mounted on the outside wall of the cave (out-cave) and a through-wall plug, which the gearbox drive shaft passes through. Typically, the drive shaft will terminate at a highly reliable in-cave drive mechanism used to drive in-cave equipment (i.e., a rack and pinion drive assembly). Through-wall drives are designed to provide an engineered seal around the wall plug drive shaft and the through-wall plug liner, which is encast into the wall. See Figure 2.1-9.

2.1.8.3. Hazardous Situations

Hazards associated with through-wall drives include:

1. Drive shaft seal failure which could result in migration of contamination up the driveshaft through the wall plug.

The set of Important to Safety SSCs for the above hazardous situations (or Faults) is provided in the following tables. The tables also identify the Safety Function and the Design Safety Functions.

Figure 2.1-9. Typical Cave Layout Showing Through Wall Drive

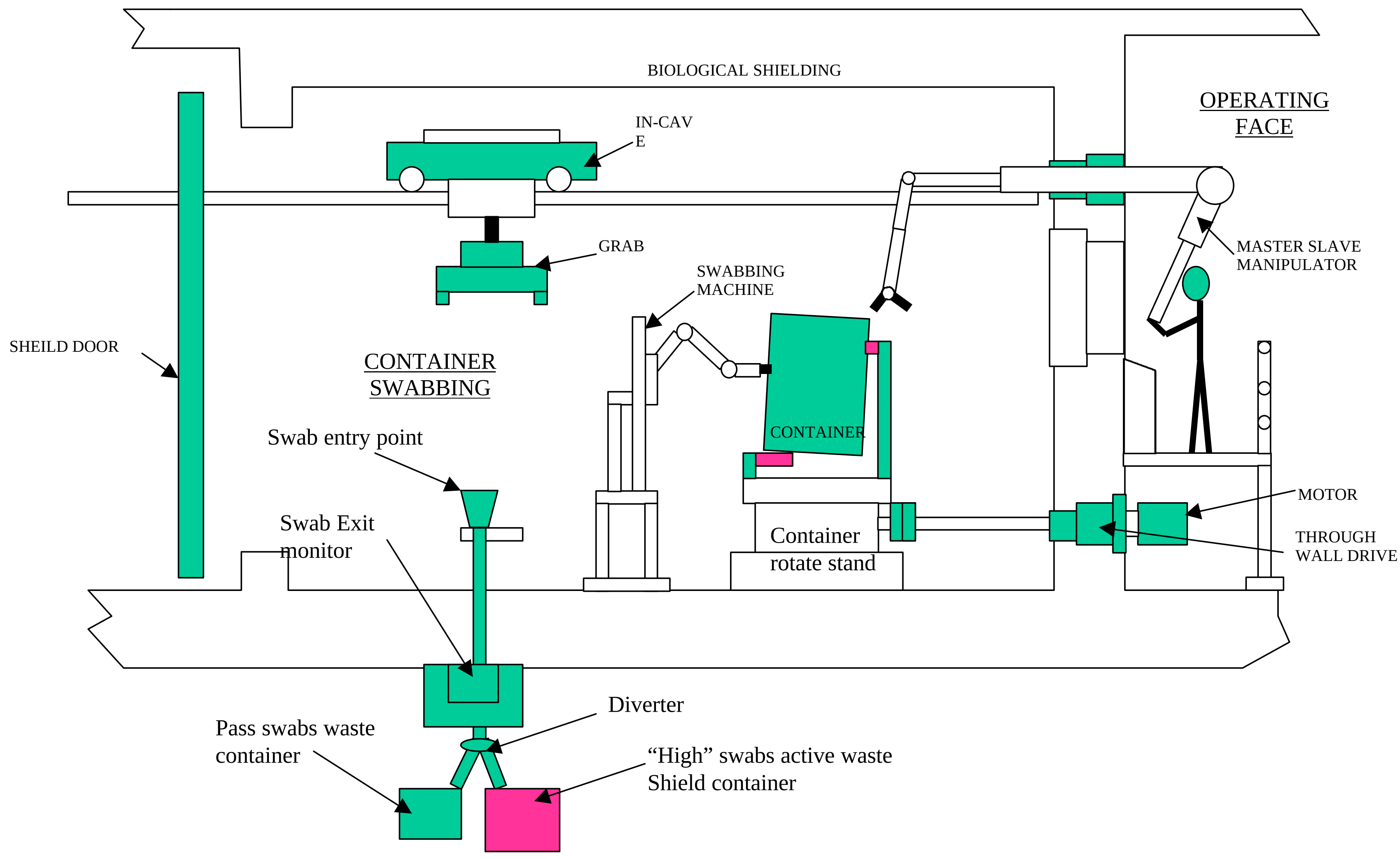


Table 2.1-8. Through Wall/Roof Drives

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of primary confinement due to drive seal failure (Also refer to Cell/ Caves for uncontrolled/ unplanned removal of penetration shield plugs) leading to worker exposure	Seals	To provide primary confinement	Multiple seals/glands provide primary confinement between cell/cave and static and dynamic components of drive system Seal interspace monitoring provisions are made to detect seal failure (and thus potential breach of confinement) NDT/inspection/QA during design and construction Material selection In service inspections Seismic design of penetrations (liners) High integrity seals welds Startup testing to verify sealing
	Leak detection system	Detects and alarms leaks aiding protection of the worker	Radiation monitoring external to cell/ cave to monitor potential migration of contamination due to seal failure
	Cell/cave ventilation system	To maintain pressure differential between cell/ cave and out-cell areas promoting air flows from areas of low contamination potential to areas of high contamination, during normal and breach conditions	Cell vent system designed to achieve postulated breach flow conditions

2.1.9. Ultrafilters

2.1.9.1. Purpose

Ultrafiltration will be used to remove entrained solids from the low activity waste (LAW) feed and complexed strontium and transuranic elements (TRU) from the envelope C feed. This extract addresses confinement issues, hazards associated with ultrafiltration processes, are addressed under unit operations.

Ultrafilters are installed in process cells. The design of the ultrafilters allows removal without loss of cell confinement. Ultrafilter assemblies are non-maintainable items and on failure, they are removed from the process environment and disposed.

2.1.9.2. Description

The ultrafiltration process consists of two parallel ultrafilter circuits. During operation, only one circuit will be operational at one time.

Ultrafilter circuits are designed to allow for periodic backwashing. Backwashing maintains filter performance, increases unit life, and reduces entrained or residual radioactivity.

Ultrafilters will be designed to be remotely removable. Disposal strategies for the ultrafilters are currently under review; however, removal procedures will follow those identified for remotely maintainable pumps. The ultrafilter unit is built into a cartridge assembly which is removable for replacement. The cartridge is withdrawn from the fixed outer casing either into a shielded flask via gamma gates for transport to a remote facility for disposal.

The ultrafilter arrangement incorporates two confinement barriers between the pumped fluid and the operating area. The interspace between these barriers, which is formed by the fixed outer casing, is provided with a combined leak detection and vent connection.

The first confinement barrier is between the process connections interspace and is provided by double elastomer seals. If both these seals should fail, the leakage is drained by the fixed casing leak detection and vent connection to a leak detection point. The leak detection line, in addition to providing seal failure detection, maintains a negative pressure relative to the operating area which also provides ventilation during cartridge withdrawal exercises.

Figure 2.1-10 indicates the main components of a removal ultrafilter assembly.

2.1.9.3. Leak Detection

Provisions for leak detection are similar to those used on the remotely maintainable valves and pumps. Figure 2.1-11 indicates a typical leak detection system configuration.

2.1.9.4. Hazardous Situations

Hazards associated with confinement/shielding of the remotely removable ultrafilters are:

1. Loss of confinement/shielding due to seal failure, or
2. Unplanned/unauthorized removal of the ultrafilter/shield plug assembly.

If the seals on the ultrafilter assembly and at the biological shielding to fail, there is a potential for contamination to migrate from the primary or secondary confinement into the operator areas.

Special purpose removal equipment, in the form of a flask/gamma gate system, is required to safely remove the ultrafilter assembly for disposal. Strict administrative procedures and controls must be in place to ensure that only the correct equipment and support facilities are used.

The set of Important to Safety SSCs for the above hazardous situations (or Faults) is provided in the following tables. The tables also identify the Safety Function and the Design Safety Functions.

Figure 2.1-10. Typical Remotely Removable Ultrafilter

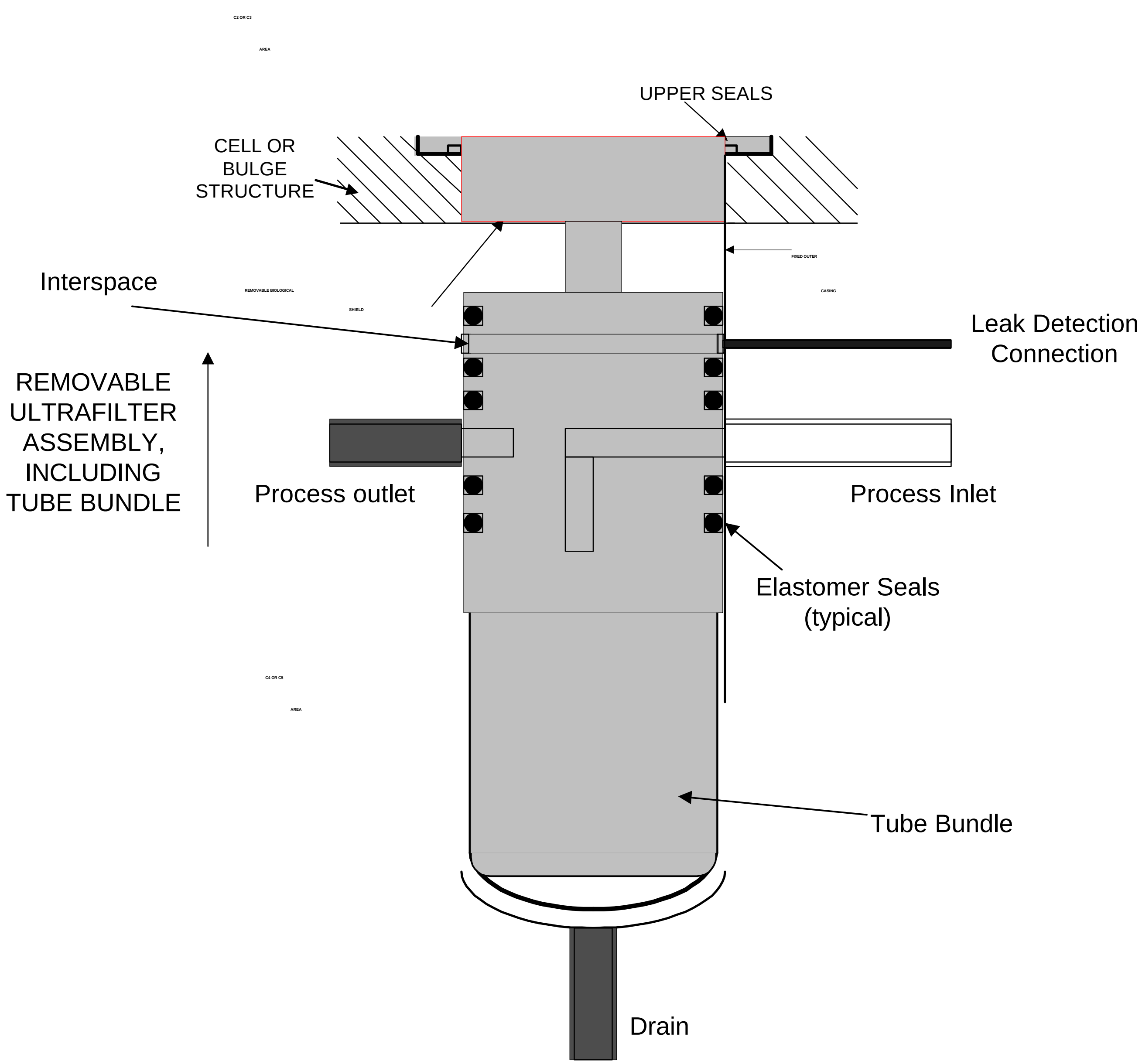


Figure 2.1-11. Typical Remotely Removable Ultrafilter Leak Detection System

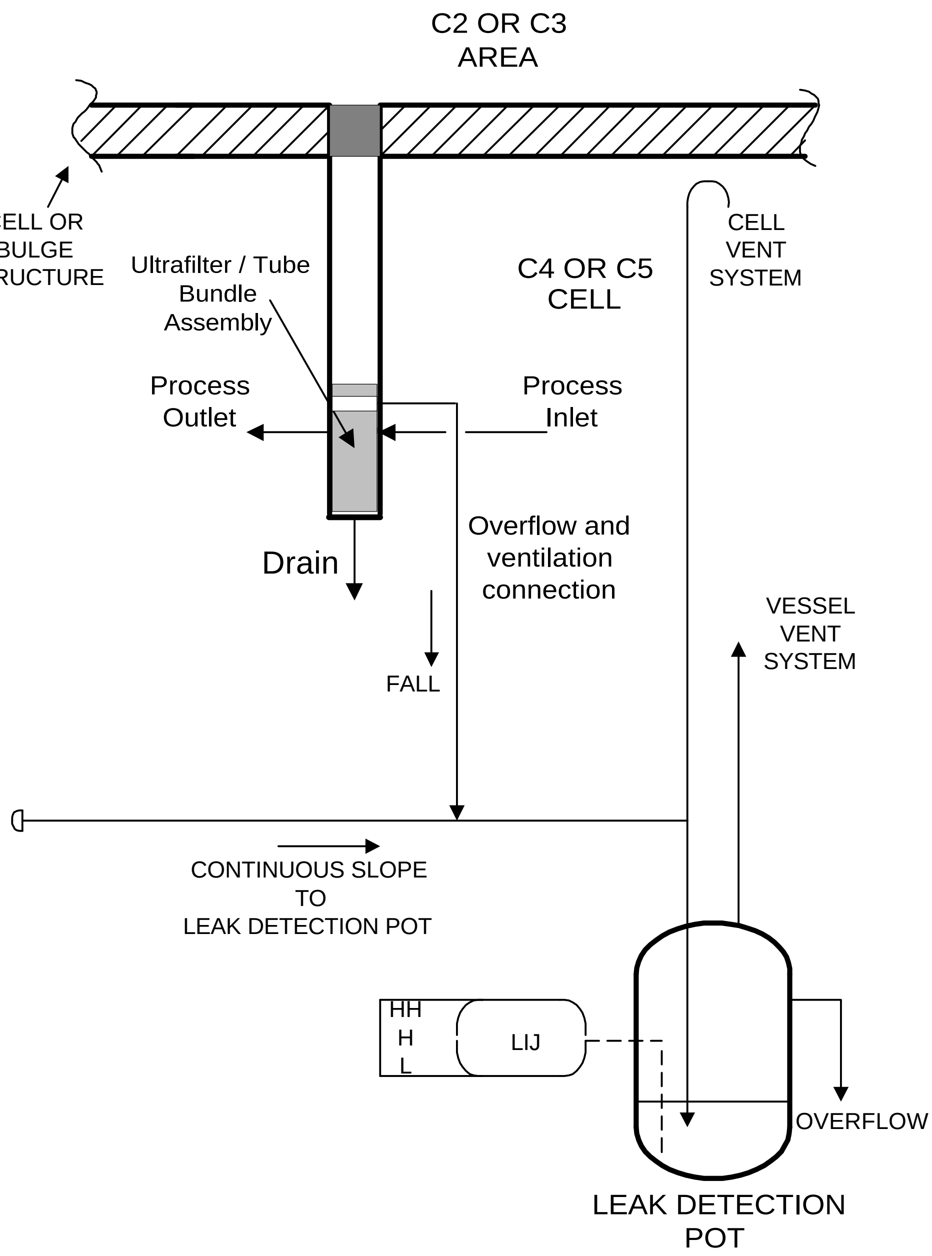


Table 2.1-9. Ultrafilter

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of primary confinement due to elastomer seal failure	Ultrafilter seal	To provide primary confinement	High integrity seals Multiple elastomer seals between the cell roof and the active liquor. Negative pressure (cell ventilation) applied to the interspace between elastomer seals Startup testing to verify sealing integrity
	Roof seal	Provide primary confinement for through cell penetration	High integrity seals Startup testing to verify sealing integrity Radiation monitoring from cell top to monitor potential contamination migration due to seal failure
	Leak detection system	Engineered route for recovery of leak process fluids	Drainage route from outer casing to a leak detection system (vessel, instrument) to detect leak.
Loss of cell secondary confinement due to requirement for ultrafilter removal	Ultrafilter outer casing/seal assembly	To provide cell confinement	Ultrafilter casing design enables unit removal without breach of cell confinement Seals between casing and through the roof liner protect confinement. NDT/inspection/QA during design and construction Material selection In service inspections Seismic design

2.1.10. Normal Operations

2.1.10.1. Description

The Category 1 methodology has identified faults and then ITS SSC's to give protection. This process has been carried out against each system area. However, for a facility such as TWRS-P, there are radiological hazards associated with normal operation that needs to be addressed. This section ensures that these hazards are recognized and that the appropriate ITS SSC are identified.

Shielding and confinement comprise the primary features of the plant which provide protection during normal operation.

2.1.10.2. Hazardous Situations

Specific normal operational safety requirements of individual systems are discussed under the particular system. The following tabulation describes provisions to address the general facility hazards of Direct Radiation and Internal Dose that inevitably result from the storage and handling of radioactive materials.

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
Direct Radiation	Cell walls	Shielding (note that all passive shielding also represents a physical barrier and affords access control)	Passive Radiation checks performed during startup
	Wall boxes	Shielding	Passive Penetrations to accept wall boxes are tapered or stepped to prevent shine paths
	Plugs	Shielding	Passive Not manually removable Stepped to prevent shine paths
	Windows	Shielding	Passive Not manually removable Stepped to prevent shine paths Fluid filled windows will not be employed.
	Shield doors	Shielding and access control	Not manually movable Stepped to prevent shine paths Controlled by gamma monitor interlock and procedural controls
	Gamma gates	Shielding	Not manually movable Doors cannot be manually opened and have interlock control
	Bulges and local shielding	Shielding	Passive. Inadvertent removal not credible. Stepped to prevent shine paths
	Flasks (casks)	Shielding	Passive except for doors Doors cannot be manually opened and have interlock control

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
	Radiological "R" zoning: • Gamma alarms (including personal) • Barriers	Access control Prevention of inadvertent entry to and prompting of evacuation from high dose areas	Gamma alarm system has multiple detector elements Procedural controls will be trained and managerially enforced Personal alarmed dosimeters are used to control exposure when there is a known risk
	Autosample units	Limit operator exposure during sampling operations No manual intervention is required and unit is shielded	Passive in respect of shielding for normal operation Maintenance intervention, if required, would be under procedural control and would be further protected by personal alarmed dosimeters and gamma/activity monitors in local areas
	Sample pneumatic transfer system	Limit operator exposure during sample transfer by speed of transfer, hence short exposure time	See Section 2.5.10 for details of fault protection against carrier coming to rest
	Decontamination facilities	Limit operator exposure during hands on maintenance operations	Operator access is under procedural control and would be further protected by personal alarmed dosimeters and gamma/activity monitors in local area.

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
	Source term control systems: • Gamma monitors • Interlocks • Sampling facilities • Sending facilities	Ensure source terms and design shielding provision compatibility is maintained by preventing transfer of high source term fluids to design designated “low active” areas of plant	Duplicate monitors, and duplicate flow interlocks and alarms where continuous streams are involved Tankage to allow sample - sentence where batch streams are involved Interlocks on transfer without sample result Monitor/alarm back-up
	Berms	Shielding of cross-site transfer lines	Designed to resist wind and precipitation erosion Condition checked by operators
Internal Dose	Vessels	Confinement of liquors	Stainless steel and 100% weld radiographed/non-destructive tested
	Melters	Confinement of vitrification feeds and products	Passive confinement. Refractory wear rate monitored.
	Pipework: • In cell • Out cell	Confinement of liquors	All primary confinement pipework is stainless steel, continuously welded, 100% radiographed/non destructive tested Out cell pipework is co-axial and is provided with leak detection.
	Pipeline components (valves, pumps etc)	Confinement of liquors	Seals are duplicated and are pressure purged to ensure that any leakage is into process area. Purge failure is alarmed
	Vessel vent system	Confinement of liquors, aerosols, gases, and airborne solids	See description of system in Section 2.2.2 Pretreatment Vessel Vent System.

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
	Melter offgas systems	Confinement of liquors, aerosols, gases, and airborne solids	See description of system in Section 2.2.3 "LAW/HLW Melter Offgas and Vessel Vent System"
	Cell walls	Confinement of aerosols, gases, and airborne solids (in conjunction with C5 vent system)	Passive. Overall air leakage rate into cell from all components is confirmed satisfactory during testing
	Wall boxes/seals	Confinement of aerosols, gases, and airborne solids	Passive
	Plugs	Confinement of aerosols, gases, and airborne solids	Passive Cannot be manually removed
	Windows	Confinement of aerosols, gases, and airborne solids	Passive Cannot be manually removed
	Inlet filters	Ensure adequate flow velocity during normal operation	Include blowback protection Changed periodically under procedural control
	Shield doors	Confinement of aerosols, gases, and airborne solids	Not manually movable Under interlock and procedural controls.
	Personal Access Doors	Access control to potentially contaminated areas	Under interlock and procedural control Entry through sub changeroom to prevent spread of activity into operating area Cascaded ventilation system to prevent movement of activity into operating area
	Linings	Confinement of liquors	Stainless steel and 100% weld radiographed/non destructive tested

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
	Sumps	Confinement of liquors. Indication of presence of liquors	Stainless steel and 100% weld radiographed/non destructive tested Level measurement and alarm is provided
	Gamma gates	Confinement of aerosols, gases, and airborne solids	Not manually movable Doors not manually openable and under interlock control. protection
	Cabinets and gloveboxes: • Box or cabinet • Ventilation • Self seal couplings • Lute seals • Self venting 3 way valves • Drain • Gloves • Posting and bagging out facilities	Confinement of, aerosols, gases, airborne solids and spilled liquors	Cabinet is passive Boxes checked for sharp edges Checking of gloves prior to and after use Routine changing of gloves Operators wear respirator if activity is known to be present during glovebox operations
	Flasks	Confinement of aerosols, gases, and airborne solids	Passive except for doors Doors not manually openable and under interlock control.
	Autosample units	Confinement of aerosols, gases, and airborne solids during sampling.	Cabinet is passive. See specific section for details of fault protection for active elements system. Maintenance intervention if required would be under procedural control and would be further protected by local activity in air monitoring and PPE.

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
	Sample transfer system: • Fans • Filters • Tube • Carrier • Bottle	Confinement of liquors, aerosols, gases, and airborne solids	Bottle, carrier and tube are all passive
	Radiological "C" zoning: • Beta in air monitoring • Alpha in air monitoring • Personnel monitoring and change facilities • Barriers, access control systems and training • Personnel Protective Equipment • Cascade ventilation system. • Sub changerooms for access into areas of higher activity.	Access control. Prevention of inadvertent entry to and prompting of evacuation from high airborne activity areas	Airborne radiation Monitor System has multiple detector elements Procedural controls will be trained and managerially enforced Ventilation system interlocked to prevent reverse flow if a higher activity ventilation system fails
	Decontamination facilities	Prevention of excessive activity levels on/in area of equipment for maintenance Confinement of liquors, aerosols, gases, and airborne solids	Sampling of wash liquors, radiation monitoring, activity in air monitoring, procedural controls on entry to facility and on requirements for PPE
	Cell (C5) vent system:	Confinement of aerosols, gases, and airborne solids	See description of system in Section 2.2.1 "Process Building Ventilation Systems"
	C3 vent system	Confinement of aerosols, gases, and airborne solids	See description of system in Section 2.2.1 "Process Building Ventilation Systems"

Table 2.1-10. Normal Operations

Hazard	ITS SSCs	Safety Function	Design Safety Feature
	C2 vent system	Detection and alarm of any abnormal discharge or of activity entering facility	See description of system in Section 2.2.1 "Process Building Ventilation Systems"
	Stack: • Flues • Monitors	Dispersion and monitoring of discharged activity.	Flues are passive Monitors duplicated, battery backed, alarm on failure Backed up by sampling